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Effects of regulated streamflows on the Sycamore Alluvial Woodland riparian community

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EFFECTS OF REGULATED STREAMFLOWS ON THE SYCAMORE ALLUVIAL WOODLAND RIPARIAN COMMUNITY

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ABSTRACT

EFFECTS OF REGULATED STREAMFLOWS ON THE SYCAMORE ALLUVIAL WOODLAND RIPARIAN COMMUNITY

by Eric L. Gillies

The Sycamore Alluvial Woodland is a specific riparian community dominated by *Platanus racemosa* Nutt. and is distributed in the lower elevations from central to southern California. This community type is presently threatened due to impacts by gravel mining, reservoirs, recreation, and channelization. This thesis examined the effects of altered streamflows due to reservoirs and grazing effects on this riparian community. Data collection and analyses included both biological and physical parameters of eight sites influenced and not influenced by altered streamflows and four sites included analyses between grazed and ungrazed. The results of the study suggest that the Sycamore Alluvial Woodland community structure has been altered as the result of regulated streamflows. Changes include an increase in riparian macrophytes, excluding *P. racemosa*, changes in the surficial sediment composition, and an increase in non-native species within the understory. Grazing was not a contributing factor negatively affecting this riparian community.

ACKNOWLEDGMENTS

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EFFECTS OF REGULATED STREAMFLOWS ON THE SYCAMORE ALLUVIAL WOODLAND RIPARIAN COMMUNITY

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INTRODUCTION

Riparian areas are vegetated zones associated with streams, creeks, rivers or other areas of freshwater influence where the availability of water, species composition, and topography are considerably different from adjacent upland vegetation types. Dominant plant species are winter deciduous, riparian trees (phreatophytes) with associated shrubs, herbs, and sometimes woody vines. In rivers and streams, the riparian vegetative zones are usually narrow at steep elevational gradient points becoming wider as fluvial processes deposit sediments at lower elevational gradient points (Elmore and Beschta 1987). The Sycamore Alluvial Woodland, or California sycamore series (Sawyer and Keeler-Wolf 1995), is a specific riparian community type dominated by western sycamore (*Platanus racemosa* Nutt.)[1] with an understory composed of herbaceous annuals and phreatophytic shrubs that have adapted to fluvial depositional plains consisting of sandy loam to coarse alluvium substrate. This community is distributed in the lower elevations of central and southern California (Holland 1986, Keeler-Wolf 1993, Sawyer and Keeler-Wolf 1995).

Because riparian ecosystems are confined to relatively narrow corridors along water courses, destruction, degradation and fragmentation of riparian systems are common in nearly all areas of California as a result of disruptive land uses. An estimated 99% of the historic riparian habitat of California's central valley has been destroyed (Abel 1989) and over 90% has been lost in the California's southern coastal region alone (Faber et al.1989). Historic and present land uses that have removed or destroyed riparian areas include grazing, agriculture, gravel mining, flood control projects, reservoirs, and channelization. These activities continue to threaten the general biodiversity and specific

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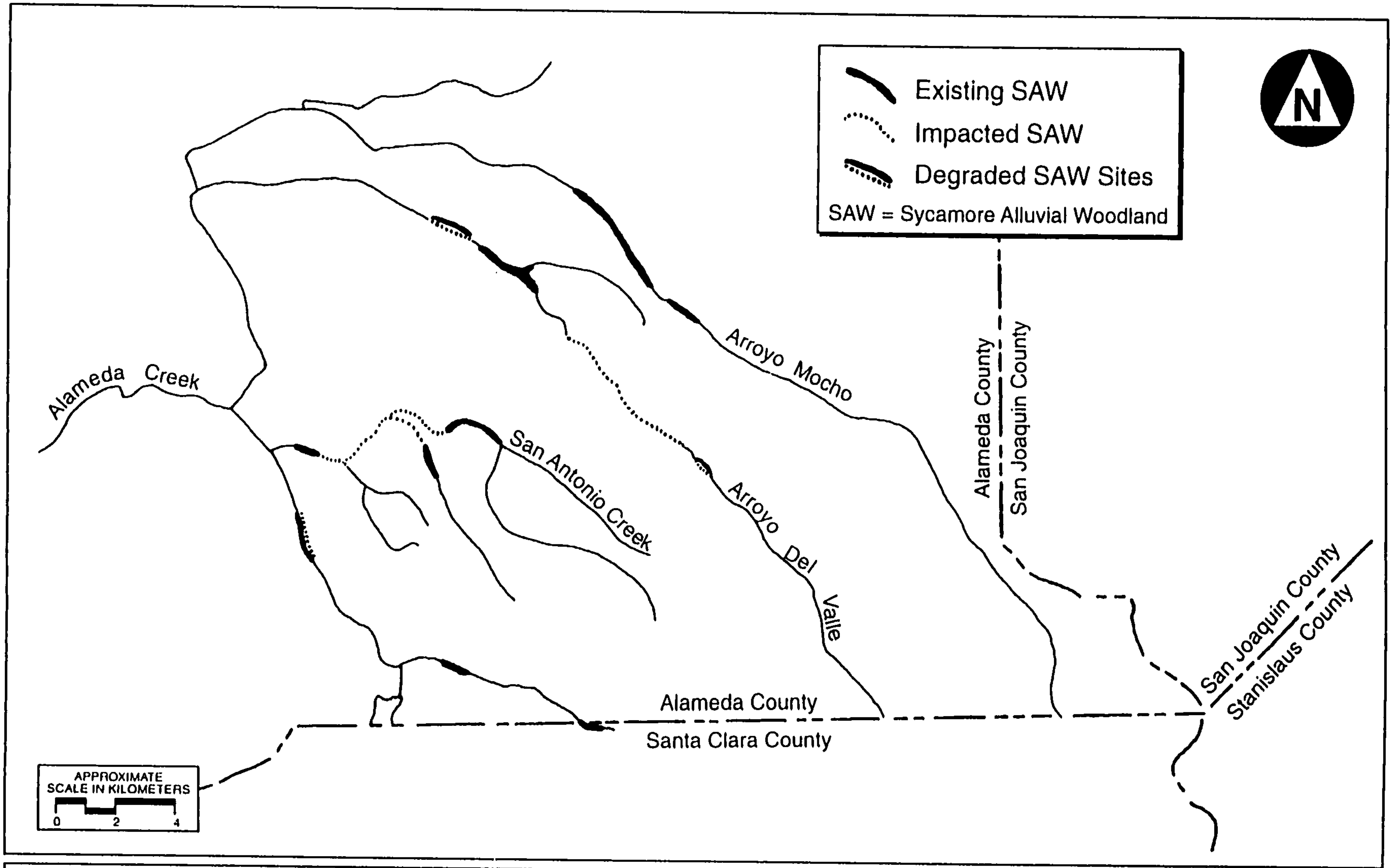
[1] Scientific nomenclature and author's abbreviations follow Hickman (1992).

species adapted to the dynamics of riparian systems or "the erosional-depositional cycle" (Buer et al. 1989).

According to the California Department of Fish and Game (1993) and Keeler-Wolf et al. (1994), the Sycamore Alluvial Woodland riparian community is threatened because only approximately 800 hectares (2,000 acres) exist within California. Approximately 160 hectares (400 acres) of the highest quality Sycamore Alluvial Woodland is found in western Merced County, in the central Diablo Range. This stand accounts for 20% of the remaining Sycamore Alluvial Woodland in California (Keeler-Wolf et al. 1994) and is presently threatened by the installation of Los Banos Grandes Reservoir proposed by the California Department of Water Resources. A pilot revegetation study was launched by the Department of Water Resources to evaluate restoration and creation techniques that may compensate for this impact (Department of Water Resources 1991, 1992, and 1994).

In southern Alameda County approximately half of the historically occurring Sycamore Alluvial Woodland has been destroyed or altered, mostly as the result of gravel mining, recreation facilities, and reservoirs. Initial work for this thesis included interpretation of aerial photos used for the *Soil Survey of the Alameda Area, California* (Welch et al. 1961) to estimate the historic extent of this community within southern Alameda County (Figure 1). The installation of Del Valle Reservoir and San Antonio Reservoir account for the largest areas completely removed. Areas currently threatened in this area are those affected by gravel mining and proposed development.

In the last few decades there has been increasing concern about the effects dams and regulated flows have on riparian systems and this impact may be contributing to the decline of many types of riparian communities (Rood and Mahoney 1993). Several studies have investigated riparian vegetation growth and composition changes.



Historic and Present Extent of Sycamore Alluvial Woodland (SAW) in Southern Alameda County

FIGURE 1

changes in riparian tree regeneration rates, and other impacts on riparian plant communities as a result of altered hydrologic flow regimes (Barnes 1997, Reily and Johnson 1982, Howe and Knopf 1991, Stromberg and Patten 1989, 1992a, 1992b, Fenner et al. 1985, Bradley and Smith 1986, Rood and Heinze-Milne 1988, Bravard et al. 1986, Szaro and DeBano 1985, Johnson et al. 1976, Smith et al. 1989). All of these studies involved either willow riparian, willow-cottonwood riparian, cottonwood riparian, poplar forest, or mixed riparian community types.

Other researchers have examined the effects of regulated streamflows in relation to fluvial geomorphology and sediment transport (Williams and Wolman 1984, Chien 1985, Kondolf et al. 1987). Still others have considered both riparian vegetation and its relation to the fluvial geomorphology (Harris 1987, Asplund and Gooch 1988, Menges and Waller 1983, Hupp and Osterkamp 1985, Jemison 1993). These studies, however, did not account for the effects of altered streamflows within the riparian system. There has been little to no study of the effects of altered flow regimes on the Sycamore Alluvial Woodland community type. A study of this impact should consider the physical conditions that are an integral part of this specific community type.

The Sycamore Alluvial Woodland was one of the first plant communities classified by the California Department of Fish and Game as a threatened community (Keeler-Wolf 1993) and there is a necessity to clearly define this community and identify the potential threats to existing stands. Keeler-Wolf et al. (1994) have contributed to this effort by researching and surveying all existing stands throughout California, collecting quantitative data clearly defining the community, and qualitatively assessing the human impacts that may be threatening the integrity of this habitat. Matheny (1989) has studied the relationship of water availability and *P. racemosa* health in Livermore, California. This study documented poor health in *P. racemosa*, potentially as a result of an upstream reservoir creating unnatural fluctuation of the surface and groundwater hydrologic regime. Glinsky (1977), Shanfield (1981), and Bock and Bock (1989) have studied regeneration of sycamores and provide information that indicate that grazing may have an indirect negative impact on sycamore regeneration. These studies and studies by Smith (1989) and Finn (1991), however, found few direct effects on sycamores due to cattle grazing, because sycamore is not considered palatable (Glinsky 1977, Martin 1979).

Platanus racemosa is also subject to sycamore anthracnose (*Gnomonia platani* Kelb.), an airborne fungus, spread by rainfall that will typically defoliate trees and kill new twig growth. The severity of this disease may be related to temperature and late spring rains (Yarwood 1951, Hepting 1971). Holstein (1981) reported that large western sycamore stands in Alameda and Contra Costa counties are severely stressed by anthracnose. Because these stands are located in the northwestern limit of their range, the cooler temperatures and more precipitation during May compared to southern California stands may be the contributing factor of greater anthracnose stress (Holstein 1981).

Several areas with existing Sycamore Alluvial Woodlands within the Diablo Range in central California were analyzed in this study. I used ecological sampling methods to collect quantitative and qualitative data on the physical and biological community structure. These data were used to assess the Sycamore Alluvial Woodland community structure under specific human induced disturbances, in particular, grazing and water regulation or disruptive flow regimes as a result of significant water related projects (i.e., reservoirs).

I compared differences in the Sycamore Alluvial Woodland community structure between sites influenced by regulated or altered flow (i.e., reservoirs) and sites not influenced by regulated or altered flow (control sites). The physical and biological parameters tested included surficial sediment composition, vegetation composition, understory cover and composition, and abundance of non-native and upland species. Other parameters tested in this study included the relationship between *P. racemosa* regeneration (sapling/suckers) and geomorphic feature (i.e., primary and secondary channels, floodplain terraces, and hummocks) and the effects of grazing influences. *Platanus racemosa* regeneration and non-native species cover at grazed sites were compared to sites with little to no grazing.

The data collected for this study are designed to provide a quantitative evaluation of the effect altered streamflows and grazing may have on the Sycamore Alluvial Woodland. The study also provides insight on potential management approaches of existing Sycamore Alluvial Woodland sites.

RELATED RESEARCH/LITERATURE REVIEW

A review of the relevant literature indicates that relatively few studies have been conducted on western sycamores or the Sycamore Alluvial Woodland community in relation to altered streamflows. Most of the studies on western sycamores have included grazing effects, health, and reproduction. Two primary studies specific to the Sycamore Alluvial Woodland community type were an extensive community classification and distribution study by the California Department of Fish and Game (Keeler-Wolf et al. 1994) and an ecological characterization study by Finn (1991) in southern California.

Riparian areas, including the Sycamore Alluvial Woodland, are dynamic systems relying on the natural disturbance factors of flooding and erosion and deposition of sediments. This hydrologic regime creates fluvial landforms and a medium for the establishment and perseverance of vegetation that have adapted to such regimes (White 1979, Hupp and Osterkamp 1985).

Fluvial disturbance is important to riparian ecosystems because it provides a mosaic of geomorphic landforms and creates different successional stages that are in dynamic equilibrium (Lowe 1964, White 1979, Asplund and Gooch 1988). Different riparian species and vegetation types are adapted to the different seral stages, disturbance intervals, and fluvial landforms. For example, pioneer vegetation being established on a newly exposed gravel bar will have a different species composition than a riparian type that has been isolated from active disturbance.

Plant succession is a principle that presents a directional change of species composition in a given plant assemblage through time (Barbour et al. 1987). The amount of time for successional change is dependent on several factors, including intervals between natural disturbances and types of vegetation and species affected by or adapted to disturbance regimes. Natural succession within the riparian landscape may be altered by external factors, including changes in natural flooding frequency and fluvial factors such as climate change, channel migration, or reservoir construction. This change may result in a different composition of seral stages in the landscape and may create a new medium for the establishment of a different set of species (Bravard et al. 1986, Szaro and DeBano 1985). The hypotheses tested in this thesis are based upon the principle that riparian communities are dynamically balanced with the natural disturbance regime of flooding, which creates the proper conditions for the perseverance of specific riparian species (Asplund and Gooch 1988, White 1979).

Sycamores (*Platanus* spp.), similar to other common riparian macrophytes (*Populus* spp., *Salix* spp.), have adapted to the disturbance of flooding. Life history characteristics of these species include the ability to reproduce asexually, produce many wind and water dispersed seed crops, tolerate flooding, produce many sucker sprouts following flood damage, and disperse seeds during spring and early summer when winter flooding has subsided and created the moist medium required to stimulate and promote seed germination. Characteristics particular to *Platanus* spp. also include short seed viability time period following dispersal, relative shade intolerance, and fast growth (USDA 1948, 1965, 1974, White 1979, Asplund and Gooch 1988). A study on *Platanus wrightii* Wats., a closely related species to *P. racemosa* (Hsiao 1973), also found that seed germination had a narrower range of tolerance to environmental conditions including water stress, pH, salinity, and temperature when compared to *Populus fremontii* Wats. and *Salix gooddingii* Ball (Seigel and Brock 1990).

Rivers and streams have the ability to adjust physical parameters in order to transport their streamflows and sediment loads. External factors, including local topography, lithology, climate, and vegetation, contribute to shaping the morphology of water courses (Morisawa 1985). These factors influence the amount of streamflow and sediment load transported through the fluvial system; and cause a stream morphology that carries the load efficiently.

A common geomorphic pattern in the Sycamore Alluvial Woodland community is a braided stream channel morphology. This type of stream pattern is often associated with areas of high discharge particularly where the stream can not carry the coarser materials for the given stream gradient and where stream banks are not cohesive enough to maintain a single channel. These conditions result in the creation of overbank spilling, wider and shallower channels, and deposition of greater amounts of the coarser material with silt and clay lacking (Leopold and Wolman 1957, Allen 1965, Osterkamp 1978).

Holland (1986) stated that the Sycamore Alluvial Woodland is defined by braided channels, coarse substrates, and broad, alluvial floodplains emerging below narrow canyons. These wide alluvial floodplains located within the drainage basin receive high peak flows and discharge from the narrow canyons that supply coarser materials and can create unstable banks and braided channels. Sycamores (*Platanus* spp.) appear to have adapted to this type of physical condition. Finn's (1991) study of *Platanus racemosa* dominated alluvial channels in southern California showed seedling regeneration occurred within one meter of the active stream channel. Sudworth (1908) also describes that *Platanus racemosa* reproduction mainly and best occurs on moist exposed sand and gravel available near stream beds. Bock and Bock's (1985) study of reproductive patterns in *P. wrightii* in Arizona also showed that young trees never occurred outside the stream channel. Sigafoos' (1976) study of *Platanus occidentalis* L. in the eastern U. S. demonstrated that germination for this species requires a certain minimum threshold of sandy alluvium. Consistent with Sigafoos' study, Hupp and Osterkamp (1985) found the bottomland species, *P. occidentalis*, to be closely associated with sandy substrates having at least sixty-five percent sand, twenty percent gravel, and less than twenty-two percent fine particles. Studies by Boerner and Cho (1987), Sampson (1930), and Gordon (1969) also found *P. occidentalis* to frequently occur on outwash deltas, areas within stream reaches where sand and gravel are deposited by meltwater streams. These outwash plains or deltas are also areas of well developed braided channels (Allen 1965).

Removing or altering the critical disturbance factor of flooding and sediment transport by installing upstream reservoirs will result in changes to successional and fluvial processes. Changes in vegetation structure may become apparent in several different ways. Upland vegetation and communities may begin to encroach into the floodplain as phreatophytic species decline from drought stress and sediments stabilize (Stromberg and Patten 1989). The abundance of non-native ruderal species may increase on the floodplain and compete with native species (Howe and Knopf 1991). Increases in other phreatophytic species may occur in stream locations not naturally accustomed to perennial streamflows and inundation as a result of constant availability of water (Szaro and DeBano 1985). Lower riparian tree recruitment may occur as a result of disrupting the spring streamflows with the timing of seed dispersal for riparian species. Floodplain trees may experience water stress as the amount of floodplain being inundated during high flows decreases.

Two critical fluvial changes as a result of upstream reservoirs are the dramatic decrease of sediment loads to downstream reaches and changes in channel patterns (Petts 1979, Andrews 1986, DeBano and Heede 1987, Mount 1995). Decreases of sediment load can have a profound impact on the channel downstream. Prior to dam construction, stream channels are typically entrained to carry the sediment load. The installation of reservoirs will hold sediment loads and can create a sediment-hungry reach downstream, subsequently increasing downstream erosion that may deepen the primary channel. Channel deepening can subsequently reduce inundation of the active floodplain. Another significant change to the fluvial geomorphology is the change in the natural geomorphic channel patterns. Chein (1985) and Kondolf and Swanson (1993) have identified areas below dams where the natural braided channel pattern had been modified to a single channel. Stream reaches below reservoirs can also increase the accumulation of finer sediments in streambed gravels affecting the instream sediment composition (Kondolf et al. 1987).

HYPOTHESES

In order to determine the effects of regulated streamflow and grazing on the Sycamore Alluvial Woodland riparian community, this thesis tested several null hypotheses:

H_0: There are no significant differences in one or more community characteristics in the Sycamore Alluvial Woodland riparian community between sites influenced by regulated or altered flow and sites not influenced by regulated or altered flow as a result of water-related projects (reservoirs).

H_A: There are differences in one or more community characteristics in the Sycamore Alluvial Woodland riparian community between sites influenced by regulated or altered flow and sites not influenced by regulated or altered flow.

Community characteristics examined in this study included sediment substrate by size class, overstory and understory vegetation cover and composition, and regeneration of *P. racemosa*.

Other important null hypotheses tested in this study included the relationship between *P. racemosa* regeneration (sapling/suckers) and the geomorphic features of primary and secondary channels, floodplain terraces, and hummocks. Grazing influences on *P. racemosa* regeneration and non-native species cover within the Sycamore Alluvial Woodland community were also assessed. Specific null hypotheses included the following:

H_0: There is no significant correlation between *P. racemosa* saplings/suckers abundance and geomorphic features of the floodplain.

H_A: There is a correlation between *P. racemosa* saplings/suckers abundance and geomorphic features of the floodplain.

H_0: There is no significant difference in the abundance of *P. racemosa* saplings/suckers and understory cover of non-native species within the Sycamore Alluvial Woodland riparian community between sites influenced and not influenced by grazing.

H_A: There are differences in the abundance of *P. racemosa* saplings/suckers and understory cover of non-native species within the Sycamore Alluvial Woodland riparian community between sites influenced and not influenced by grazing.

Rejection of any of the proposed null hypotheses supports the alternative hypotheses that there is an effect.

METHODS

Study Locations

This study examined eight Sycamore Alluvial Woodland sites located in the Mt. Hamilton Range, a part of the Diablo Range of the central Coast Range, California. The Mt. Hamilton Range is underlain predominately by rocks of the Great Valley and Franciscan complexes. The range is crossed by major faults including the Calaveras and Hayward faults (Sharsmith 1945, Lindsey 1974). At all of the study sites, the soils belong to the Riverwash series, which is composed of sand, gravel, and cobble with little silt and clay and is subject to movement during runoff and flooding (Lindsey 1974, Welch et al. 1961).

The study area has a typical California Mediterranean climate with dry, warm summers and cool, wet winters. The average annual temperature throughout the study area ranges from 14° C to 16° C. Precipitation falls almost exclusively as rain. Snow occasionally occurs during cold winter storms and at the higher elevations of the Diablo Range. The average annual precipitation ranges from approximately 30 cm in the lowlands to 51-76 cm in the higher elevation areas of the Diablo Range. Specific precipitation amounts for each of the study sites are presented in Table 1 and compiled from Rantz (1974).

Four of the eight streams examined were free flowing (control) and included Arroyo Mocho, upper San Antonio Creek, and upper Alameda Creek in the northern part of the Mt. Hamilton Range and South Fork Pacheco Creek in the southern part of the range. These streams have not been altered by upstream reservoirs and have watershed sizes ranging from 66 km^2 to 99 km^2. Elevation of these streams ranged from 120 m to 210 m above sea level. Channel slope within these stream reaches ranged from 0.4 percent to 1.3 percent (Table 1).

The remaining four study sites included regulated stream reaches below reservoirs including Arroyo Del Valle and lower San Antonio Creek in the northern part of the range, lower Coyote Creek in the western part of the range, and North Fork Pacheco Creek in the southern part of the range. Each of these dams has been in place for 30 years or more and they were completed on these streams between 1934 and 1968. Watershed sizes for these streams ranged from 103 km^2 to 588 km^2. Elevations of these streams ranged from 100 m to 150 m above sea level. Channel slope within these stream reaches were similar to the control reaches ranging from 0.4 percent to 1.5 percent

Table 1. Summary of the eight Sycamore Alluvial Woodland study sites examined within the Diablo Range in central California. Site reference numbers correspond to reference numbers on the location maps (figures 2-7).

Streams Studied	Average Elevation (m)	Channel slope (%)	Watershed Size (km^2)	Mean Annual Precipitation (cm)†	Associated Reservoir (distance downstream)	Year Dam Completed	Site Grazed	Owner**
Free Flowing (Control)								
1. Arroyo Mocho*	210	1.2	99	43	none	--	Yes	private
3. San Antonio Creek (upper)	180	0.6	49	61	upstream of San Antonio Reservoir	--	Yes	SFWD
5. Alameda Creek (upper)	200	0.8	97	71	none	--	Yes	EBRPD
7. S. Fork Pacheco Creek*	120	1.3	66	51	none	--	Yes	private
Regulated Flows								
2. Arroyo Del Valle (lower)*	150	0.6	386	51	downstream of Del Valle Reservoir (2.5 km)	1968	Limited	LARPD
4. San Antonio Cr. (lower)*	100	0.4	103	61	downstream of San Antonio Reservoir (< 1.0 km)	1964	Yes	SFWD
6. Coyote Creek (lower)*	110	0.8	588	56	downstream of Anderson Reservoir (4.0 km)	1934	No	SCCPD
8. N. Fork Pacheco Creek*	122	1.5	174	51	downstream of Pacheco Reservoir (< 1.0 km)	1935	Yes	private

† Data from local stream gage stations (Rantz 1974).

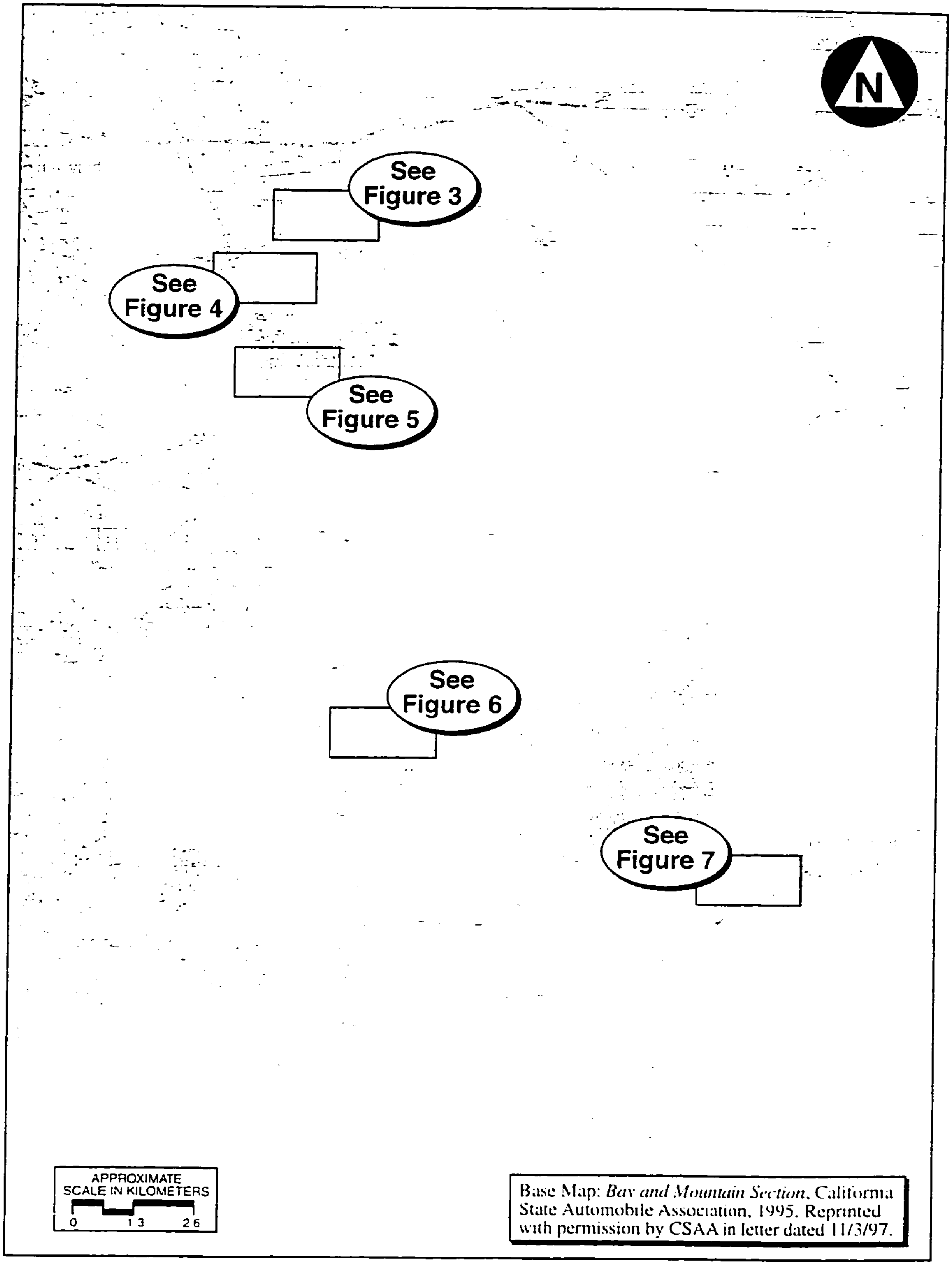
* Locations cited in California Department of Fish and Game (1993) and Keeler-Wolf et al. (1994).

** Permission to enter granted: EBRPD = East Bay Regional Park District; SFWD = San Francisco Water Department; LARPD = Livermore Area Recreation and Park Department; SCCPD = Santa Clara County Park Department.

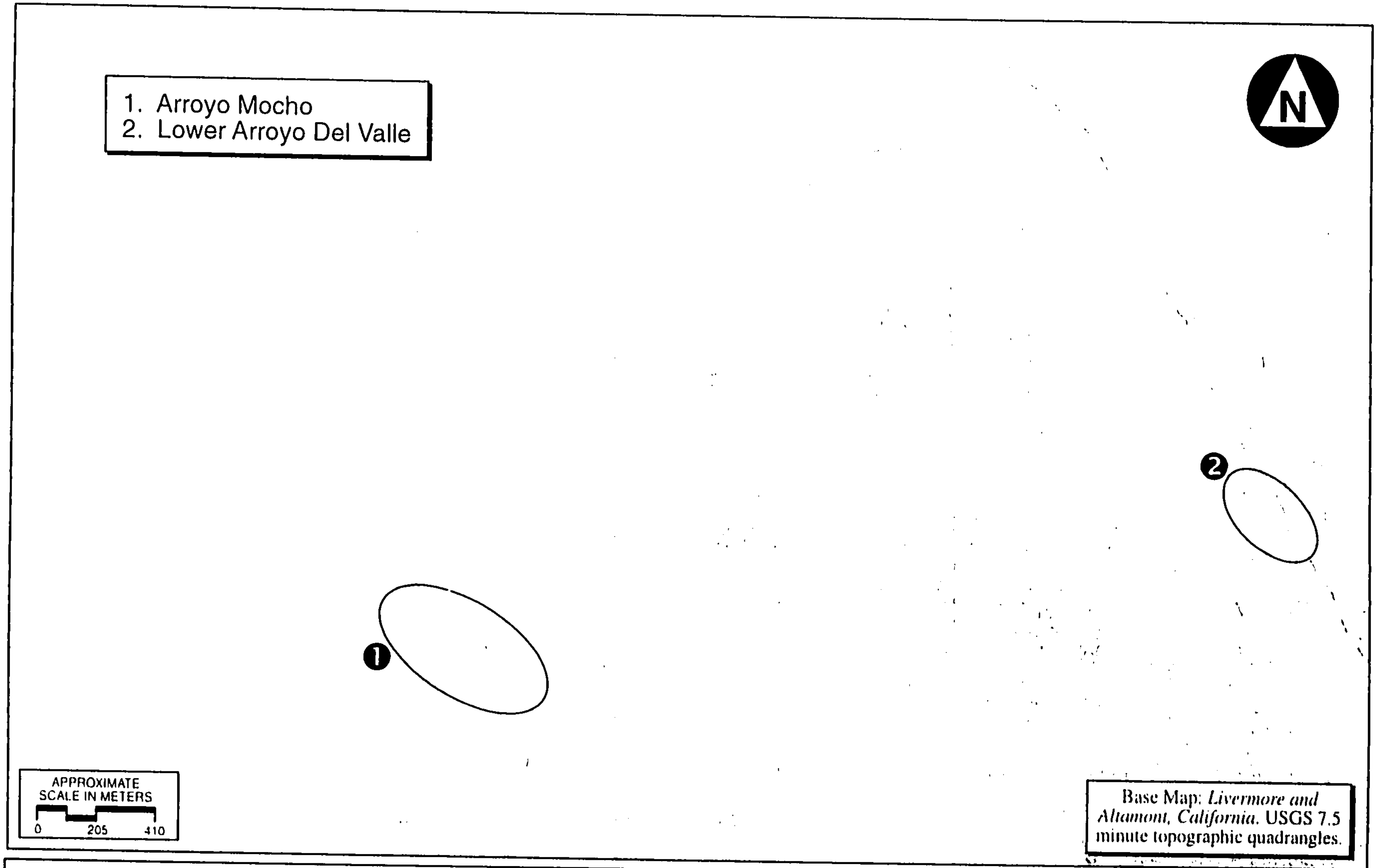
(Table 1). Figures 2 through 7 map the study site locations for each stream examined.

Limiting the study sites to a single geographic region helped to reduce the variability of climate. A study conducted by Keeler-Wolf et al. (1994) found that the Sycamore Alluvial Woodland is composed of specific "affinity groups" that further define this community and included the interior sycamore alluvial group, foothill group, southern California group, and mid-coastal alluvial group. The specific Sycamore Alluvial Woodland affinity group typically found in the study area included the mid-coastal alluvial group. This affinity group is identified as sycamore dominated stands bordering multi-channeled (braided) intermittent streams with at least a small percentage of *Quercus agrifolia* (H. & A.) Nutt. (coast live oak) and/or *Umbellularia californica* Nee. (California bay) present in the tree layer and located within the influence of summer maritime air masses.

I selected lower Arroyo Del Valle and lower Coyote Creek as sites that are ungrazed or of very limited grazing to compare the riparian community structure with actively grazed sites along lower San Antonio Creek and North Fork Pacheco Creek (Table 1, Figures 3, 4, 6, and 7). Each of these locations had upstream reservoirs resulting in regulated flow regimes reducing the variability of streamflow patterns. Arroyo Del Valle has not been heavily grazed for approximately 20 years and current grazing activities are limited to three months during the summer for reducing fuel loads (Rob Seibert, Livermore Area Recreation and Park Department Park Ranger, pers. comm., January 7, 1997). The lower Coyote Creek study site has not been grazed for over 30 years (Eric Goodrich, Santa Clara County Park Department Park Ranger, per. comm., January 7, 1998). Both lower San Antonio Creek and North Fork Pacheco Creek are actively grazed throughout the entire or most of the year.

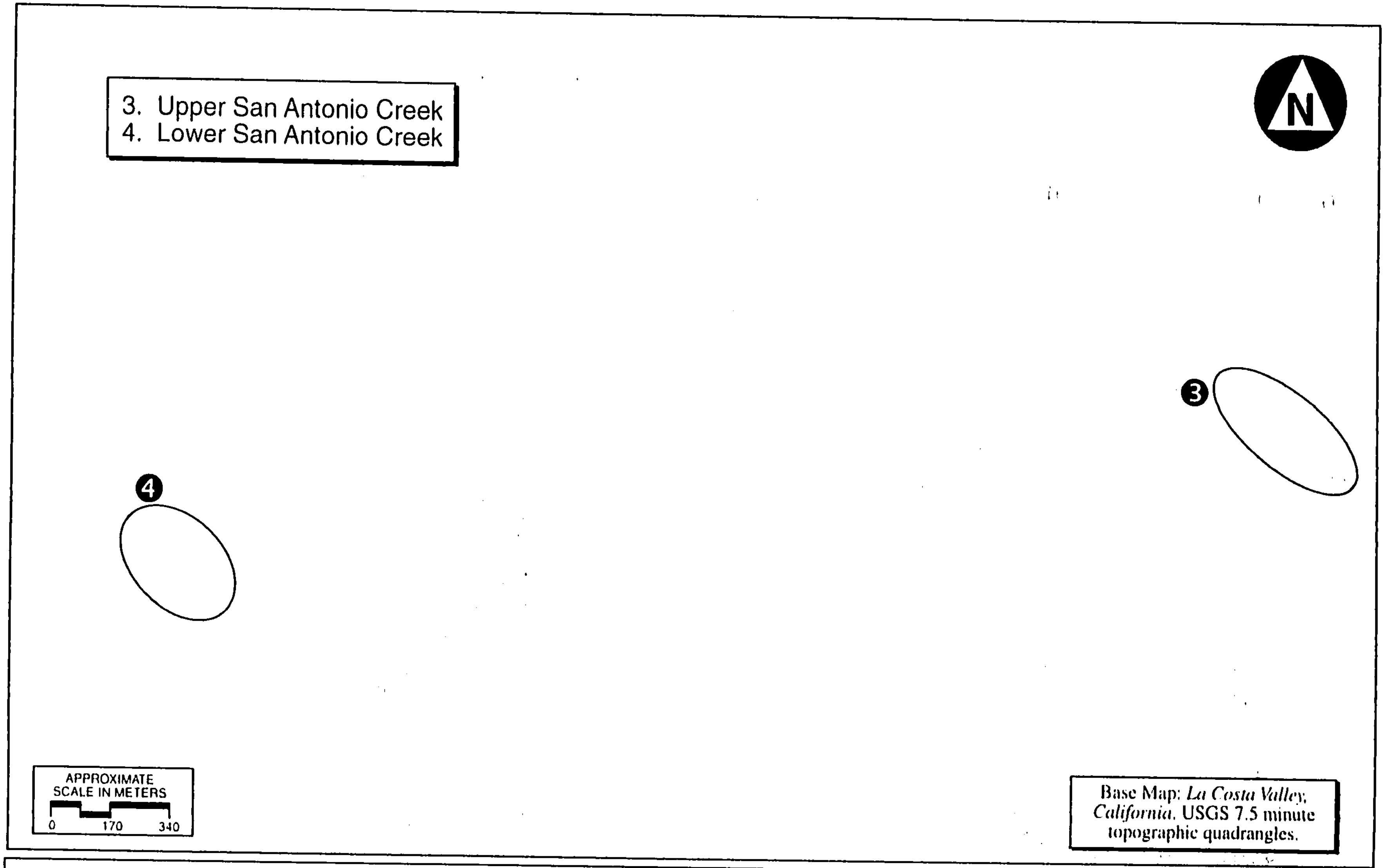


Regional Map of Study Site Locations **FIGURE 2**



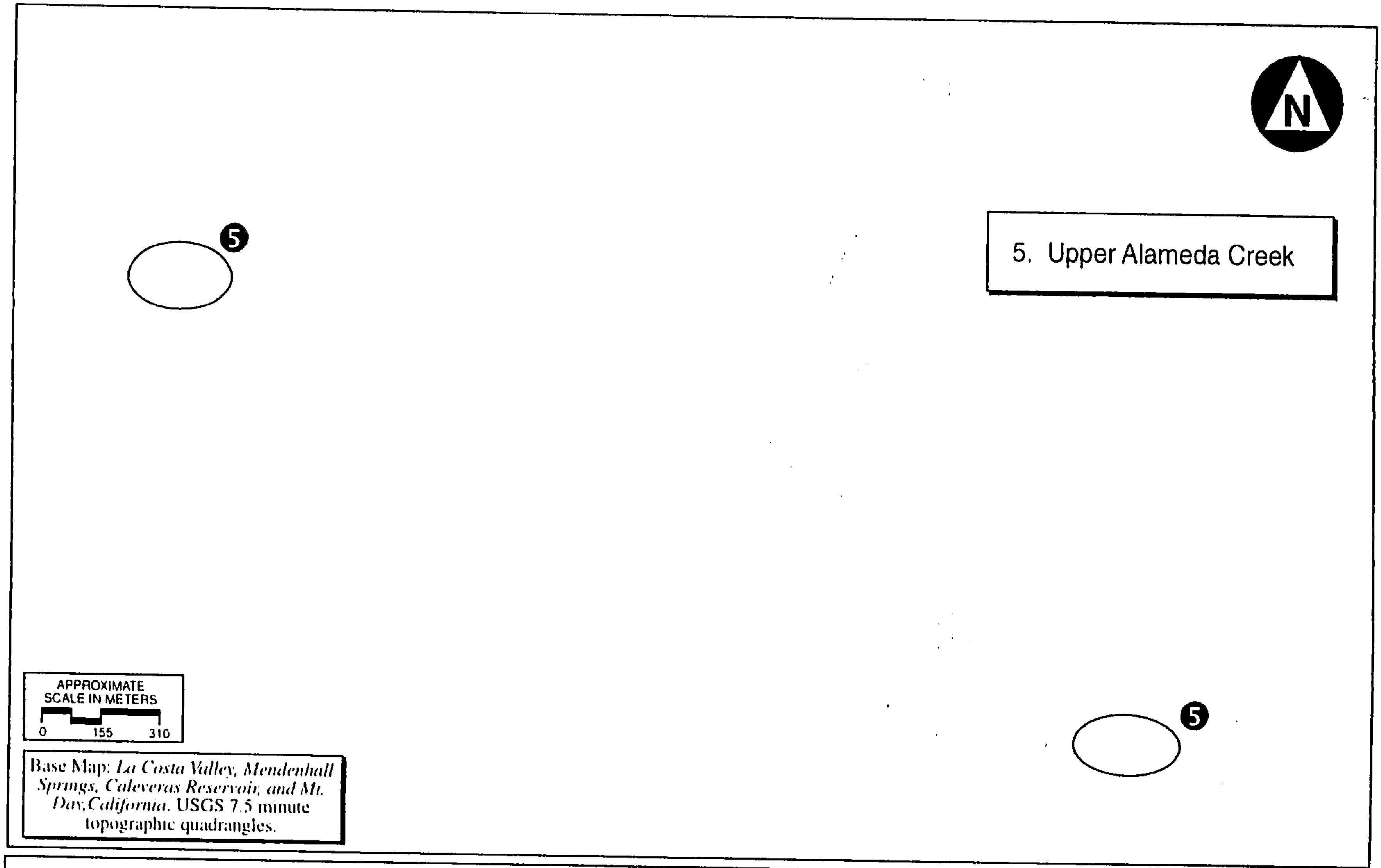
Study Site Locations: Livermore and Altamont Quadrangles

FIGURE 3



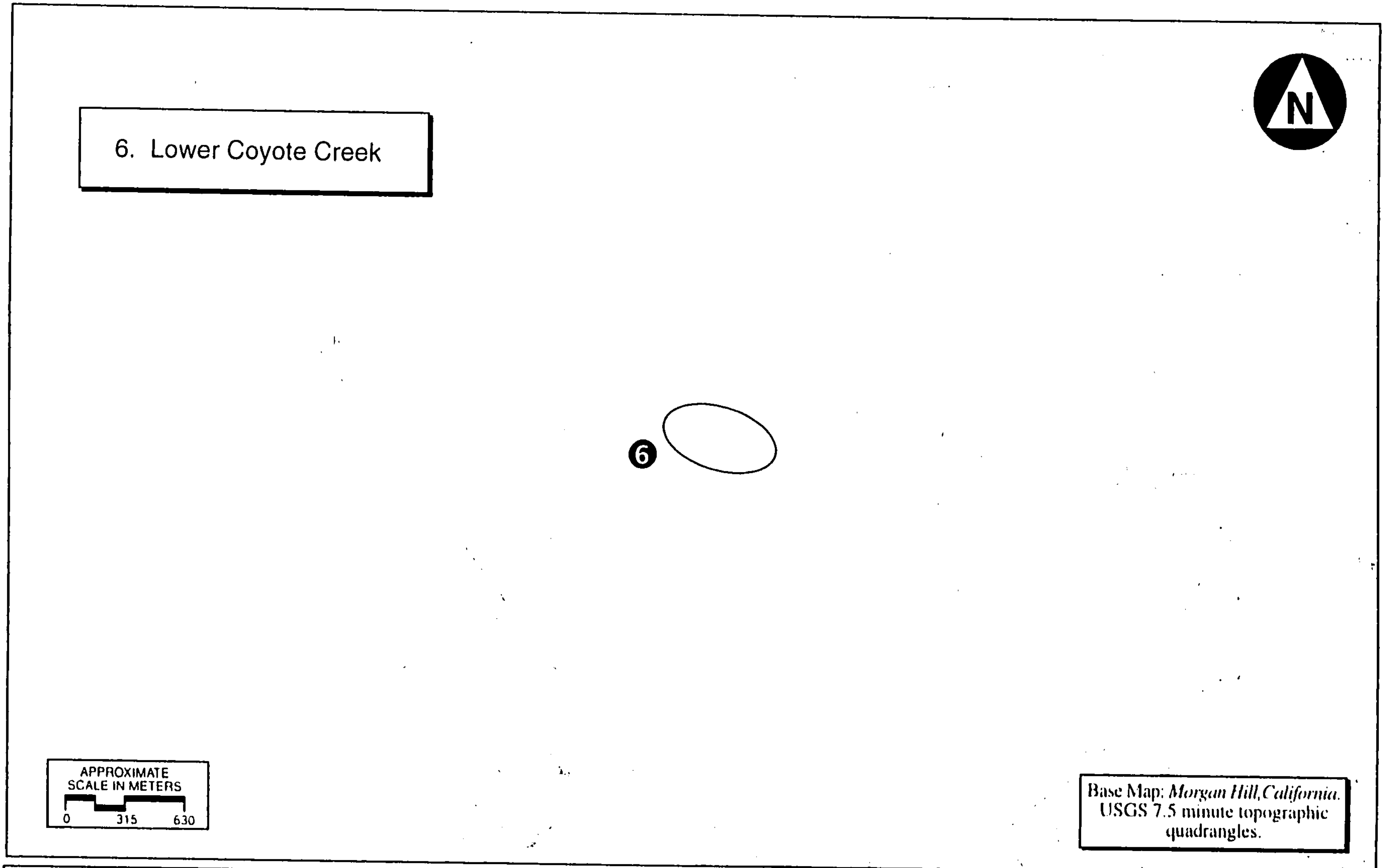
**Study Site Locations:
La Costa Valley Quadrangle**

FIGURE 4



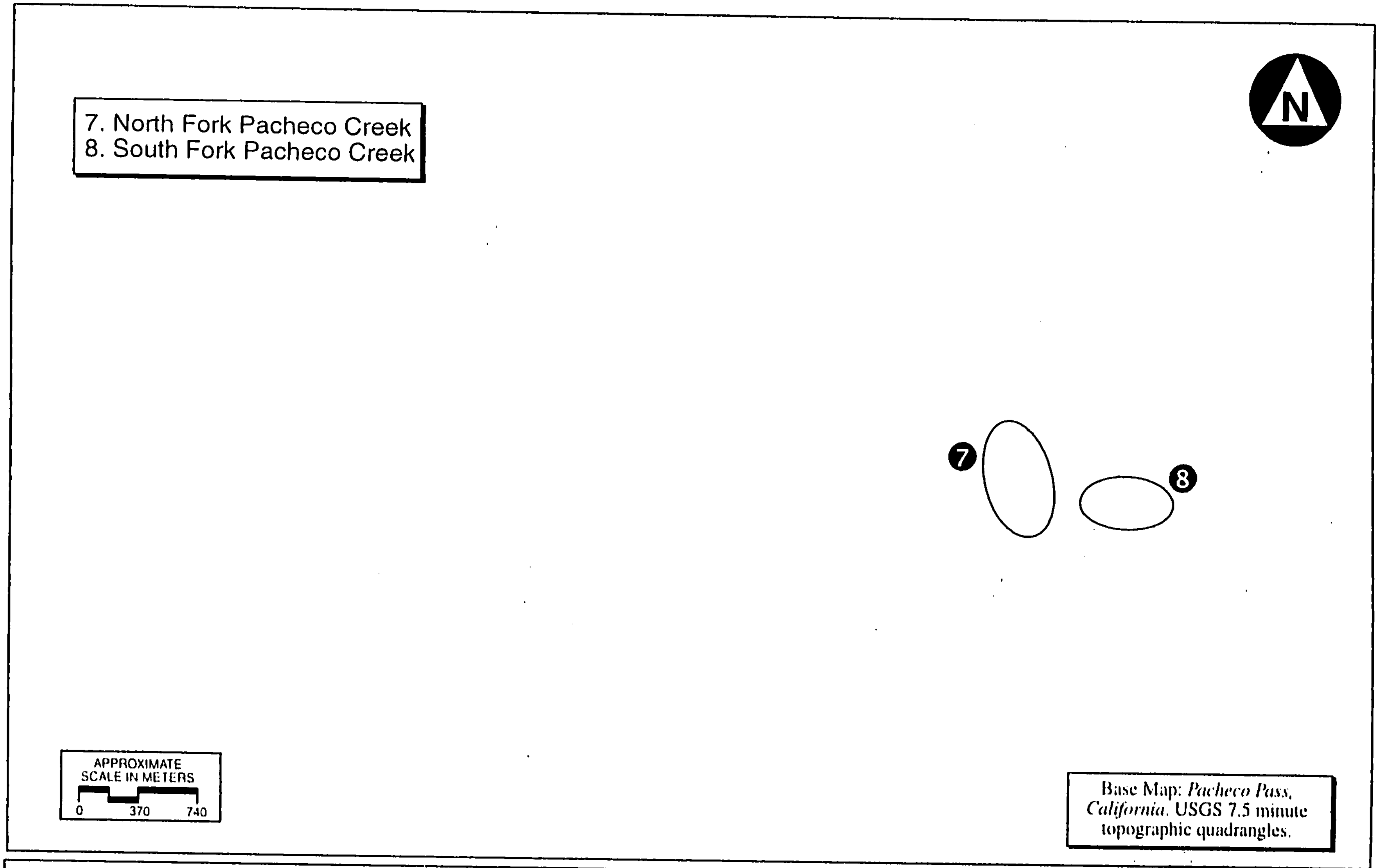
Study Site Locations: La Costa Valley, Mendenhall Springs, Caleveras Reservoir, Mt. Day Quadrangles

FIGURE 5



Study Site Location: Morgan Hill Quadrangle

FIGURE 6



Study Site Locations: Pacheco Pass Quadrangle

FIGURE 7

Data Collection

Data collection for all the study sites included vegetation and physical environment parameters. Vegetation parameters included woody species densities by size classes (seedling, sapling, suckers, and mature) and cover by strata layer (understory, shrub layer, and overstory). Data collected on the physical environment included surficial sediment composition (cobble, gravel, sand, mud) and geomorphic features (primary and secondary channels, floodplain terraces). These data were used to compare the control sites and the sites that have been affected by upstream reservoirs. The comparison between grazed and ungrazed or of very limited grazed sites included only the vegetation parameters.

I selected an approximate 500-meter stream reach within each stand and included three to six randomly selected transects laid perpendicular to the primary stream channel. The length of the transect ranged from 29 meters to 105 meters of all of the study sites, with an average length of 53 meters within free flowing reaches and an average length of 70 meters at the sites below reservoirs. No transect extended further than the edge of the floodplain or Sycamore Alluvial Woodland riparian community.

A total of 21 transects were sampled within free flowing stream reaches (control) and 20 transects were sampled within regulated streamflow reaches or below reservoirs. For each transect, the line-intercept method was used to gather both vegetation cover data for each strata layer and surficial sediment data (Gordon et al. 1992). Geomorphic surfaces (primary channel, secondary channels, flooplain terraces) were also identified along the transect. All taxa identified in the samples followed botanical nomenclature by Hickman (1992). Surficial sediment composition by definition of size classes is usually an arbitrary parameter (Gordon et al. 1992); therefore, for the purposes of this study I used a collapsed version of size classes following USDA (1979). The sediment texture size classes include: cobble/medium gravel (> 8 mm), fine gravel/coarse sand (8 mm to 0.5 mm), sandy/silt (0.5 mm to 0.0625 mm), silty/clay (< 0.0625 mm), soil/loam (mixture of gravel, sand, silt, and organic material of developing soil derived from alluvium parent material).

Each geomorphic feature (i.e., primary channel, secondary channel, floodplain terrace) intercepted by the transect line included 5 m x 20 m quadrats. These quadrats were randomly selected from the transect line within the width of a particular geomorphic feature and the longer axis of the quadrat laid perpendicular to the transect line. A total of 43 quadrats were sampled above reservoirs and 54 quadrats below reservoirs. The 43 quadrats of the unregulated flow reaches included 21 quadrats within the primary channels and banks, 12 quadrats within the secondary channels and banks, and 10 quadrats on floodplain terraces. The 54 quadrats of the regulated flow reaches included 18 quadrats within the primary channels and banks, 12 quadrats within the secondary channels and banks, and 24 quadrats on floodplain terraces. Data from these quadrats included density data for all trees greater than 1 cm diameter at breast height (dbh), shrubs and young trees (seedlings, saplings/suckers). This sampling design provided data from approximately one to two percent of each sampled stream reach. Sampling occurred from June 10 to August 24, 1995.

Data Analysis

The data from the 41 transects and 97 quadrats were compiled to estimate constancy (percent of transect samples in which a species occurred), mean cover of all species intercepted by the transects, mean absolute densities, and mean cover of surficial sediment composition for each study location. One-way analysis of variance (ANOVA) was used to test densities of the riparian and upland species, sediment substrate composition, and vegetative cover between the regulated streamflow and free flowing stream (control) reaches. I used ANOVA to examine non-native understory cover and *P. racemosa* regeneration in grazed versus ungrazed sites.

I used simple linear regression analysis to examine the relationship between floodplain geomorphic features and the regeneration of *P. racemosa* (Greig-Smith 1964). Regression analysis included all the quadrat data for *P. racemosa* sapling/suckers (n=97). ANOVA was then used to test the significance of the regression analysis between the geomorphic features and *P. racemosa* regeneration. Table 2 provides a summary of research parameters, sampling methods and data analyses for this study. All statistical analyses were tested and rejected null hypotheses at 95 percent or greater confidence limits.

Table 2. Summary of the methods used for examining the effects of altered streamflow regimes and grazing on the Sycamore Alluvial Woodland community.

Research Parameters	Sampling Method	Statistical Analysis
Analysis Between Altered and Unaltered Streamflows		
Density (size classes)	quadrats	ANOVA
Vegetation cover (strata layers)	line-intercept	ANOVA
Surficial sediment composition (size classes)	line-intercept	ANOVA
P. racemosa regeneration	quadrats	ANOVA
Analysis Between Grazed and Ungrazed Sites		
Vegetation cover (strata layers)	line-intercept	ANOVA
P. racemosa sapling/sucker densities	quadrats	ANOVA
Analysis of Regeneration with Geomorphic Features		
P. racemosa regeneration with geomorphic features	quadrats	linear regression

RESULTS

Community Structure

The vegetative structure of the Sycamore Alluvial Woodland downstream of reservoirs and the control stream reaches was assessed by comparing over- and understory cover of all species intercepted. densities of woody plant by size classes. and sycamore regeneration. Physical attributes of the community included surficial sediment composition by size classes and geomorphic features. A species list was compiled for those species intercepted by the transects and constancy for each species is given for each stream location (Table 3). Appendix A provides representative photographs of the study stream reaches below reservoirs and the control sites.

The overstory data for woody plants showed that *P. racemosa* cover was similar between sites downstream and upstream from reservoirs ($\bar{x}$ = 34.0% and $\bar{x}$ = 28.9%, respectively)(Table 4). The survey period occurred in 1995 following late spring rains that subsequently resulted in a heavy sycamore anthracnose outbreak throughout the study sites. Adjacent upland community components, largely composed of *Aesculus californica* (Spach) Nutt., *Quercus agrifolia, Q. lobata* Nee., and *Umbellularia californica*, that were found with the Sycamore Alluvial Woodland community were similar in combined cover among free flowing ($\bar{x}$ =7.6%) and below reservoir stream ($\bar{x}$ = 8.4%) reaches (Table 5). There was a significant increase (ANOVA P = 0.004) in riparian species cover (including *Populus balsamifera* ssp. *trichocarpa* (T. & G.), *P. fremontii* ssp. *f., Salix exigua* Nutt., *S. laevigata* Bebb., and *S. lasiolepis* Benth.), excluding *P. racemosa*, downstream of the reservoirs (Table 5, Figure 8).

The data collected from the quadrats includes number of trees greater than 1 cm dbh and the number of shrubs per 0.10 hectare. As expected, *P. racemosa* was the most abundant tree in both regulated ($\bar{x}$ = 5.7/0.10 ha) and unregulated ($\bar{x}$ = 3.0/0.10 ha) stream reaches. Shrubs were dominated by *Baccharis salicifolia* in both regulated ($\bar{x}$ = 19.1/0.10 ha) and unregulated ($\bar{x}$ = 55.6/0.10 ha) stream reaches (Table 6). Similar to the combined riparian species cover data, the combined riparian species, excluding *P. racemosa*, but including *Populus balsamifera* ssp. *trichocarpa, P. fremontii* ssp. *f., Salix exigua, S. laevigata*, and *S. lasiolepis*, was significantly greater (ANOVA P = 0.01) below reservoirs compared to the free flowing stream reaches (Table 5, Figure 10). Upland species densities were considerably higher below reservoirs ($\bar{x}$ = 10.4/0.10 ha) than the control sites ($\bar{x}$ = 1.9/ 0.10 ha); however, this difference was not significant

(ANOVA $P = 0.19$; Table 5). This greater value may have been due to one of the samples below Del Valle Reservoir that had found 26 *Aesculus californica* seedlings.

The analysis of understory cover composition downstream of reservoirs and control sites compared the amount of unvegetative cover and non-native species composition. The amount of open ground upstream ($\bar{x} = 55.7\%$) was significantly higher (ANOVA $P = 0.00001$) than the downstream reaches ($\bar{x} = 17.6\%$) of the reservoirs. The amount of non-native, annual grassland cover in the downstream reaches of reservoirs ($\bar{x} = 60.9\%$) was nearly doubled compared to the control reaches ($\bar{x} = 32.8\%$)(Table 4). The total amount of non-native species cover was significantly higher (ANOVA $P = 0.000001$) below reservoir reaches ($\bar{x} = 71.7\%$) compared to free flowing reaches ($\bar{x} = 33.0\%$)(Table 5, Figure 9).

Table 3. List of vascular plants of the Sycamore Alluvial Woodland study area, Alameda and Santa Clara counties. All species found along the transect are listed. Values refer to the constancy (percent of plots containing the species) of each taxa and are as follows: 1 = 5-15%, 2 = 16-25%, 3 = 26-35%, 4 = 36-45%, 5 = 46-55%, 6 = 56-65%, 7 = 66-75%, 8 = 76-85%, 9 = 86-95%, 10 = 96-100%.

		Free Flowing (Control)				Regulated Flow Reaches			
Scientific Name	Vernacular Name	Arroyo Mocho (n=3)	Upper San Antonio Cr. (n=6)	Upper Alameda Cr. (n=7)	South Fork Pacheco Cr. (n=5)	Arroyo Del Valle (n=5)	Lower San Antonio Cr. (n=5)	Lower Coyote Cr. (n=6)	North Fork Pacheco Cr. (n=4)
Trees and Large Shrubs									
Aesculus californica	California buckeye		2	3		6	2		
*Nicotiana glauca**	Tobacco tree	3							
Populus balsamifera ssp. *trichocarpa*	Black cottonwood						2		
P. fremontii ssp. *f.*	Fremont cottonwood					2			
Platanus racemosa	Western sycamore	10	10	10	10	10	10	8	10
*Prunus cerasifera**	Cherry plum							2	
Quercus agrifolia	Coast live oak			3	2	4	2		5
Q. kelloggii	California black oak								2
Q. lobata	Valley oak		2	3			2	3	
Rhamnus californica ssp. *c.*	Coffee berry							2	2
Salix exigua	Sandbar willow							3	
S. laevigata	Red willow	3				4			7
S. lasiolepis	Arroyo willow						8	2	
Sambucus mexicana	Blue elderberry			1				2	5
Umbellularia californica	California bay			1	2		2		2
Shrubs									
Artemisia californica	California sagebrush	3		1		2			
Baccharis douglasii	Marsh baccharis					2			
B. pilularis	Coyote brush			1		2		3	
B. salicifolia	Mulefat	10	8	1	6	8	6	10	5
Brickellia californica	California brickellbush			6	2	6			

Table 3 Cont.

Heterotheca oregona var. *o.*	Golden aster			1		8			
Keckiella brevifolia	Keckiella					2			
Lotus purshianus var. *p.*	Deer weed			1					
*Marrubium vulgare**	Horehound					2		5	2
Mimulus aurantiacus	Sticky monkeyflower			1					
Rosa californica	California rose			1		2		2	
*Rubus discolor**	Himalayan blackberry							3	
R. ursinus	California blackberry					2			
Symphoricarpos albus var. *laevigatus*	Snowberry			1		2	4		
Toxicodendron diversilobum	Poison-oak			3	2			2	
Herbs									
Artemisia douglasiana	Mugwort					2		8	
*Brassica nigra**	Black mustard	10	8		8	8		10	5
Carduus spp.*	Italian thistle	3	8		2	2			5
*Centaurea calcitrapa**	Purple star thistle								2
*C. solstitialis**	Yellow star thistle							2	2
*Conium maculatum**	Poison hemlock							3	
*Dipsacus sativus**	Fuller's teasel							3	
Epilobium densiflorum	Willow herb			1	2			2	
Eremocarpus setigerus	Turkey mullein	3	5						
Eschscholzia californica	California poppy					2			
*Foeniculum vulgare**	Sweet fennel						2		
Galium aparine	Goose grass					2	4	2	
Heliotropium curassavicum	Heliotrope		3						
Hypochaeris spp.*	Cats-ear					2			
*Lactuca serriola**	Prickly lettuce					2			
Lotus purshianus var. *p.*	Lotus						2		
Lupinus bicolor	Miniature lupine					4			
*Mentha pulegium**	Pennyroyal						6	2	
*Picris echioides**	Bristly ox-tongue					2		2	
*Plantago lanceolata**	Plantain							3	

Table 3 cont.

Polygonum spp.	Knotweed				2	4	2		2
*Raphanus sativus**	Radish							2	
*Rumex crispus**	Curly dock					2	6		2
R. salicifolius	Willow dock				4				
*Senecio vulgaris**	Groundsel	3							
*Silybum marianum**	Milk thistle					2		7	
*Sonchus oleraceus**	Common sow thistle							2	
Stachys ajugoides var. *rudis*	Hedge nettle							2	
Urtica dioica ssp. *holosericea*	Stinging nettle							2	
*Verbascum thapsus**	Woolly mullein					2			
Vicia americana var. *a.*	American vetch					4			
Grasses and Sedges									
Avena spp.*	Wild oats	10	10	4	8	10	10	8	
*Bromus diandrus**	Ripgut grass	10	5	7	8	10	10	10	5
*B. hordeaceus**	Soft chess	3	5	4					
B. madritensis ssp. *rubens**	Red brome			3					
Carex spp.	Sedge						2		
*Cynodon dactylon**	Bermuda grass	10		1		2	4		5
*Cynosurus echinatus**	Dogtail grass								
Cyperus eragrostis	Umbrella sedge					4	6	3	
Eleocharis spp.	Spike rush				2				
Elymus glaucus	Blue wildrye		2		2				
Hordeum spp.*	Foxtail	3				2			5
Juncus bufonius	Toad rush				2				
Juncus spp.	Rush					2			
*Lolium multiflorum**	Italian ryegrass		5		4	2	2		
*Piptatherum miliaceum**	Smilo grass					4		2	
*Polypogon monspeliensis**	Rabbit's-foot grass			1				2	

* indicate non-native species

Table 4. Cover of vascular plants of the Sycamore Alluvial Woodland, Alameda and Santa Clara counties, California. Species and cover values are identified for each study location and for unregulated and regulated stream reaches. Cover values are mean ± standard error.

Scientific Name	Free Flowing Reaches (Control)				Regulated Flow Reaches				Combined Totals	
	Arroyo Mocho (n=3)	Upper San Antonio Cr. (n=6)	Upper Alameda Cr. (n=7)	South Fork Pacheco Cr. (n=5)	Arroyo Del Valle (n=5)	Lower San Antonio Cr. (n=5)	Lower Coyote Cr. (n=6)	North Fork Pacheco Cr. (n=4)	Unregulated Streamflows (n=21)	Regulated Streamflows (n=20)
Overstory Composition										
Trees and Large Shrubs										
Aesculus californica		1.9 ± 1.9	2.4 ± 1.8		9.4 ± 4.4	6.5 ± 6.4			1.3 ± 0.0	4.0 ± 2.0
Platanus racemosa	24.9 ± 4.0	23.9 ± 8.0	46.5 ± 8.4	34.1 ± 9.3	30.2 ± 6.8	35.9 ± 4.8	27.1 ± 12.0	21.3 ± 4.7	34.0 ± 0.2	28.9 ± 4.1
Populus balsamifera ssp. *trichocarpa*						5.5 ± 5.5				1.4 ± 1.4
Populus fremontii ssp. *f.*					2.6 ± 2.6					--
Quercus agrifolia			4.0 ± 3.5	2.2 ± 2.2				11.2 ± 7.0	1.8 ± 1.3	2.2 ± 1.6
Quercus kelloggii								1.0 ± 1.0		--
Quercus lobata		5.1 ± 5.1	7.1 ± 5.1						3.8 ± 0.1	
Salix exigua							5.5 ± 5.5			4.2 ± 1.5
Salix laevigata	3.2 ± 3.2				6.7 ± 4.2		2.1 ± 2.1	9.6 ± 3.6	--	3.6 ± 2.3
Salix lasiolepis						14.6 ± 7.5				
Sambucus mexicana			--					1.5 ± 1.5		--
Umbellularia californica			2.3 ± 2.3	1.4 ± 1.4		6.8 ± 6.8			1.1 ± 0.0	1.7 ± 1.7
OPEN (Overstory canopy)	72.0 ± 6.4	69.1 ± 14.4	37.8 ± 6.1	62.2 ± 8.8	52.3 ± 4.5	30.8 ± 10.6	64.5 ± 13.3	55.4 ± 5.7	57.4 ± 5.8	51.2 ± 5.5
Understory Composition										
Shrubs										
Baccharis salicifolia	17.3 ± 4.2	12.0 ± 2.6	--	3.7 ± 1.6	5.1 ± 2.4	6.1 ± 5.4	2.4 ± 1.3		6.8 ± 0.1	3.5 ± 1.5
Brickellia californica			3.8 ± 2.1	--	1.8 ± 1.1				1.5 ± 0.0	--
Heterotheca oregona var. *o.*			--		1.0 ± 0.3				--	--
Rosa californica			--		1.6 ± 1.6		--		--	--
*Rubus discolor**							1.6 ± 1.6			--

Table 4 cont.

Rubus ursinus					1.0 ± 1.0		--			--
Symphoricarpos albus var. *laevigatus*			--		4.6 ± 3.7	1.6 ± 1.6			--	1.5 ± 1.0
Toxicodendron diversilobum			2.5 ± 2.3	--			1.9 ± 1.9		--	--
Herbs										
Artemisia douglasiana					1.3 ± 1.3		2.5 ± 0.8			1.1 ± 0.4
*Brassica nigra**		--					6.8 ± 5.9		--	2.0 ± 1.8
*Centaurea calcitrapa**								2.0 ± 2.0		--
*Conium maculatum**							2.4 ± 2.1			--
Epilobium densiflorum			--				1.9 ± 1.8		--	--
*Foeniculum vulgare**						1.8 ± 1.8				--
Galium aparine						1.4 ± 0.9	--			--
Hypochaeris spp.*					2.4 ± 2.4					--
Lotus purshianus var. *p.*						4.0 ± 4.0				1.0 ± 1.0
*Silybum marianum**							1.7 ± 0.8			--
Grasses and Sedges										
*Cynodon dactylon**	--					4.3 ± 3.0		8.4 ± 3.2	--	2.8 ± 1.2
Cyperus eragrostis				--		2.1 ± 1.0	--		--	--
Elymus glaucus		1.3 ± 1.3							--	
*Piptatherum miliaceum**					1.0 ± 1.0		1.6 ± 1.5			--
NON-NATIVE GRASSES†	69.2 ± 1.7	50.5 ± 4.9	11.9 ± 3.1	18.9 ± 8.0	72.6 ± 5.7	63.9 ± 6.5	53.9 ± 14.4	53.3 ± 9.0	32.8 ± 0.3	60.9 ± 5.1
OPEN (Understory cover)	11.7 ± 3.3	35.6 ± 5.3	78.5 ± 4.7	74.6 ± 8.3	7.5 ± 1.3	13.8 ± 5.6	17.3 ± 8.3	35.7 ± 12.9	55.7 ± 0.3	17.6 ± 4.2

-- = values < 1.0

* indicate non-native taxa

† Non-native grasses include species typical of the annual grassland community and predominately compose of *Avena* spp., *Bromus diandrus*, *B. madritensis* ssp. *rubens*, *B. hordeaceus*, *Hordeum* spp., and *Lolium multiflorum*.

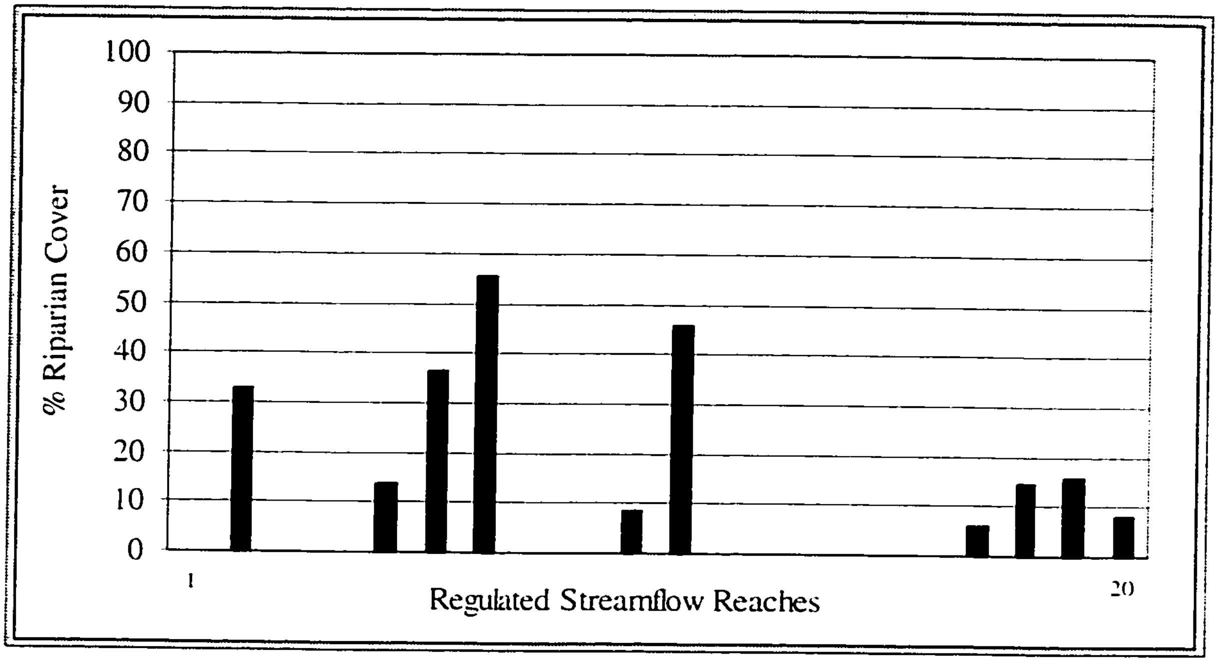
Table 5. Comparison of riparian, upland, and non-native species cover and tree density between unregulated and regulated streamflow reaches within the Sycamore Alluvial Woodland sites. Riparian species included *Populus balsamifera* ssp. *trichocarpa*, *P. fremontii* ssp. *f.*, *Salix exigua*, *S. laevigata*, and *S. lasiolepis*. Upland species included *Aesculus californica*, *Quercus agrifolia*, *Q. kelloggii*, *Q. lobata*, and *Umbellularia californica*. Cover and absolute density values are mean ± standard error.

	Free Flowing Reaches (n=21)	Regulated Streamflow Reaches (n=20)	ANOVA *P*-value	$P < 0.05$
Overstory Cover				
P. racemosa	34.0 ± 0.2	28.9 ± 4.1	0.41	
Riparian Species	--	11.8 ± 3.8	0.004	*
Upland Species	7.6 ± 3.3	8.4 ± 2.7	0.86	
Understory Cover				
Total Non-native Species	33.0 ± 5.5	71.7 ± 4.0	0.000001	*
Non-native Grasses	32.8 ± 0.3	60.9 ± 5.1	0.0005	*
Open	55.7 ± 0.3	17.6 ± 4.2	0.00001	*
	trees/0.10 ha (n=43)	trees/0.10 ha (n=54)		
Tree Density				
P. racemosa	3.0 ± 1.1	5.7 ± 1.5	0.16	
P. racemosa Sapling/Suckers	1.5 ± 0.9	2.5 ± 1.0	0.51	
Riparian Species	--	7.2 ± 2.5	0.01	*
Upland Species	1.9 ± 1.3	10.4 ± 5.6	0.19	

-- = values < 1.0

* indicate significant result

Figure 8. Graphs showing cover of riparian species (excluding *P. racemosa*) for regulated streamflow (n=20) and control reaches (n=21). Riparian species include *Populus balsamifera* ssp. *trichocarpa*, *P. fremontii* ssp. *f.*, *Salix exigua*, *S. laevigata*, and *S. lasiolepis*.



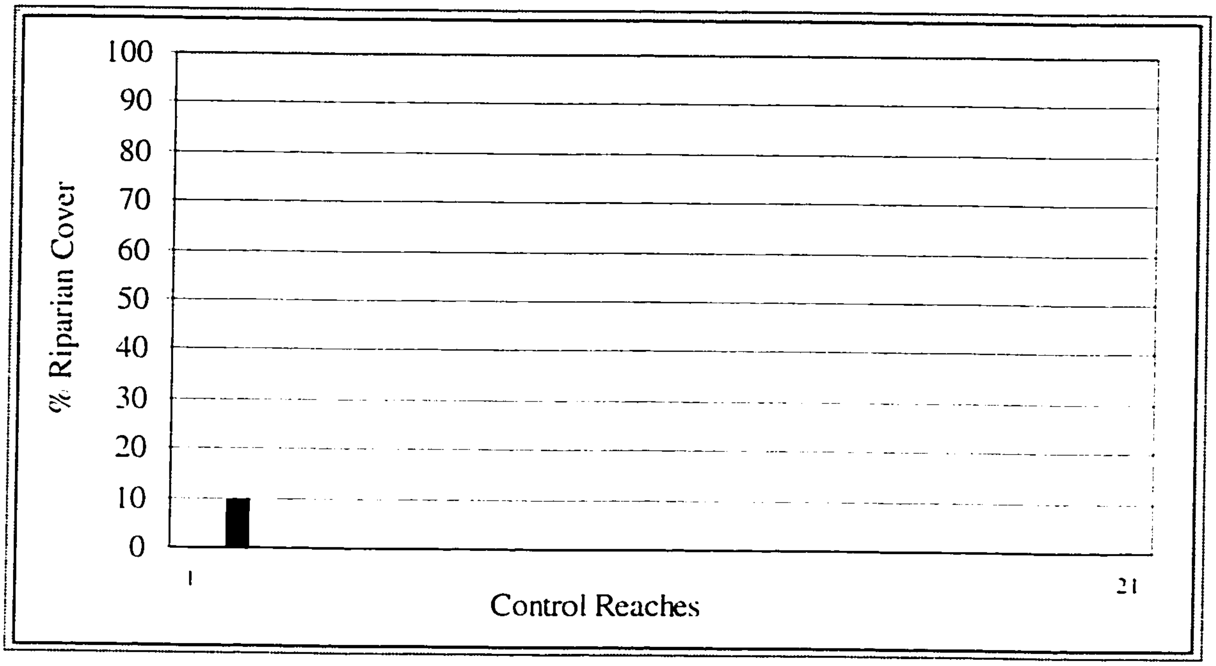
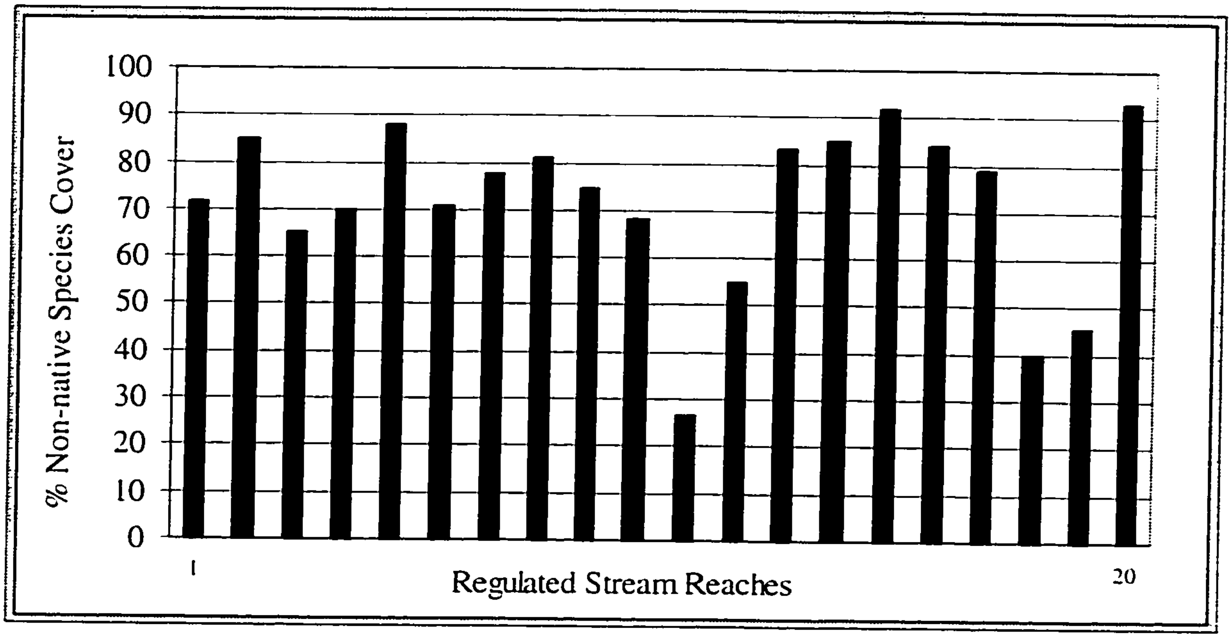


Figure 9. Graphs showing cover of non-native species for regulated streamflow (n=20) and control reaches (n=21).



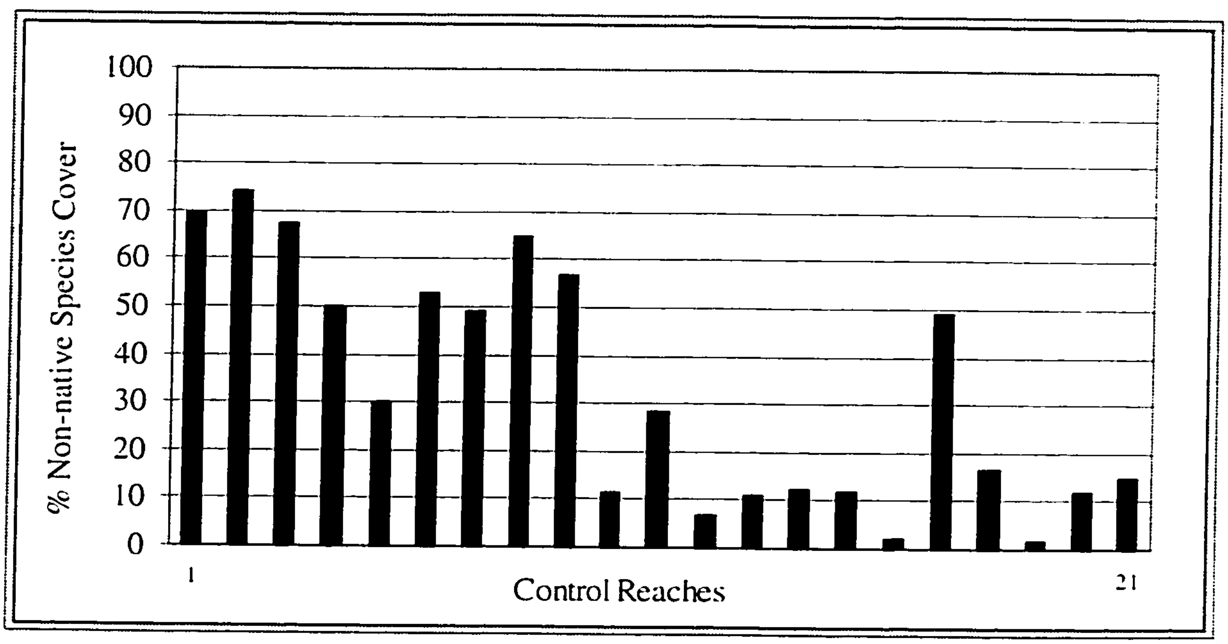


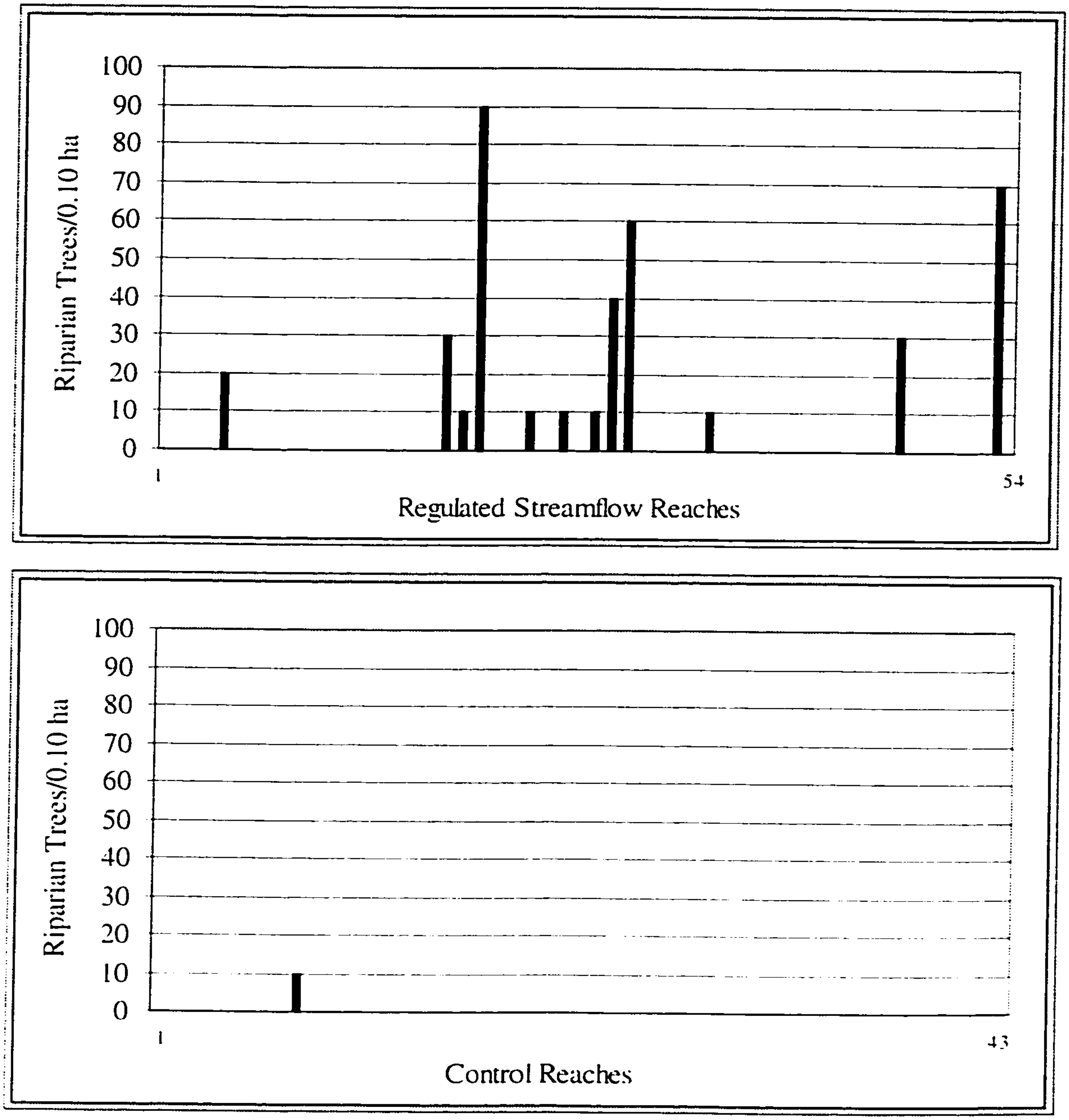
Table 6. Absolute density of trees and shrubs of the Sycamore Alluvial Woodland, Alameda and Santa Clara counties, California. Species and density values are identified for each study location amd from unregulated and regulated stream reaches. Density values are mean/0.10 ha ± standard error.

Scientific Name	Free Flowing Reaches (Control)				Regulated Flow Reaches				Combined Totals	
	Arroyo Mocho (n=8)	Upper San Antonio Cr. (n=13)	Upper Alameda Cr. (n=16)	South Fork Pacheco Cr. (n=6)	Arroyo Del Valle (n=18)	Lower San Antonio Cr. (n=10)	Lower Coyote Cr. (n=16)	North Fork Pacheco Cr. (n=10)	Unregulated Streamflows (n=43)	Regulated Streamflows (n=54)
Trees and Large Shrubs										
Juglans californica ssp. *hindsii*							--			--
Platanus racemosa	2.5 ± 1.6	--	5.6 ± 2.7	1.7 ± 1.7	3.3 ± 1.6	6.0 ± 3.1	6.3 ± 2.7	9.0 ± 5.3	3.0 ± 1.1	5.7 ± 1.5
Populus balsamifera ssp. *trichocarpa*						7.0 ± 7.0				--
Quercus lobata							--			--
Rhamnus californica ssp. *c.*			1.9 ± 1.9					1.0 ± 1.0	--	--
Salix exigua							4.4 ± 3.8			1.3 ± 1.1
Salix laevigata	1.3 ± 1.3				1.2 ± 1.2			7.0 ± 7.0	--	1.7 ± 1.5
Salix lasiolepis						6.0 ± 3.1	1.9 ± 1.9	1.0 ± 1.0		1.9 ± 0.8
Sambucus mexicana							--	2.0 ± 2.0		--
Shrubs										
Artemisia californica			1.9 ± 1.0		--				--	--
Baccharis pilularis							7.5 ± 6.9		--	2.2 ± 2.0
Baccharis salicifolia	58.8 ± 34.6	121.5 ± 31.5	--	55.0 ± 49.2	13.9 ± 6.9	67.0 ± 65.9	5.0 ± 2.0	3.0 ± 2.1	55.6 ± 14.9	19.1 ± 12.3
Brickellia californica			29.4 ± 15.8		3.9 ± 2.3				10.9 ± 6.2	1.3 ± 0.8
Heterotheca oregona var. *o.*					29.4 ± 16.2					9.8 ± 5.6
Lotus scoparius					--					--
Mimulus aurantiacus		1.5 ± 1.5	3.1 ± 2.5						1.6 ± 1.0	
Rosa californica		--			3.3 ± 3.3				--	--
*Rubus discolor**							--			--
Rubus ursinus					--					--
Symphoricarpos albus var. *laevigatus*			--		30.6 ± 30.6	44.0 ± 31.7			--	18.3 ± 11.7
Toxicodendron diversilobum					1.7 ± 1.7					--

-- = values < 1.0.

* indicate non-native taxa

Figure 10. Graph showing densities/0.10 ha of riparian species (excluding *P. racemosa*) for regulated streamflow (n=54) and control reaches (n=43). Riparian species include *Populus balsamifera* ssp. *trichocarpa*, *P. fremontii* ssp. *f.*, *Salix exigua*, *S. laevigata*, and *S. lasiolepis*.



Surficial Sediment Composition

Surficial sediment data between downstream reaches and upstream reaches is provided in Table 7. With respect to finer sediment sizes, upstream sandy/silt and silty/clay ($\overline{x}$ = 15.2% and $\overline{x}$ = 2.4%, respectively) and downstream sandy/silt and silty/clay ($\overline{x}$ = 13.4% and $\overline{x}$ = 2.7%, respectively) sites were similar. The proportion of coarser sediment (cobble/medium gravel and fine gravel/coarse sand), was significantly greater for the free flowing reaches (ANOVA $P = 0.004$ and 0.02, respectively) than for reaches below the reservoirs. The percentage of these larger sediment sizes was over twice as much at the surface of free flowing reaches ($\overline{x}$ = 32.7% and $\overline{x}$ = 22.2%, respectively) than the downstream reaches ($\overline{x}$ = 12.9% and $\overline{x}$ = 9.5%, respectively). The percent of soil/loam, mostly associated with floodplain terraces, that has developed within the floodplain of the free flowing reaches ($\overline{x}$ = 27.5%) was significantly lower (ANOVA $P < 0.00006$) compared to that of the downstream reaches ($\overline{x}$ = 61.4%) below reservoirs (Table 8).

Table 7. Cover of surficial sediment composition of the Sycamore Alluvial Woodland, Alameda and Santa Clara counties, California. Values are identified for each study location from unregulated and regulated stream reaches. Sediment texture size classes include: Cobble/medium gravel = > 8 mm; Fine gravel/coarse sand = 8 mm to 0.5 mm; Sandy/silt = 0.5 mm to 0.0625 mm; Silty/clay = < 0.0625 mm; Soil/loam = developed soil derived from alluvium parent material. Values include the mean ± standard error.

	Free Flowing Reaches (Control)				Regulated Flow Reaches				Combined Totals	
	Arroyo Mocho (n=3)	Upper San Antonio Cr. (n=6)	Upper Alameda Cr. (n=7)	South Fork Pacheco Cr. (n=5)	Arroyo Del Valle (n=5)	Lower San Antonio Cr. (n=5)	Lower Coyote Cr. (n=6)	North Fork Pacheco Cr. (n=4)	Unregulated Streamflows (n=21)	Regulated Streamflows (n=20)
Sediment Composition										
Cobble/medium gravel	5.8 ± 4.2	17.4 ± 5.2	39.1 ± 6.4	58.3 ± 14.6	13.5 ± 7.2	20.3 ± 3.2	6.7 ± 3.1	12.5 ± 9.0	32.7 ± 5.8	12.9 ± 2.8
Fine gravel/coarse sand	10.5 ± 4.5	22.9 ± 10.9	28.9 ± 6.0	19.1 ± 12.1	5.2 ± 2.5	11.7 ± 4.1	4.5 ± 3.1	19.7 ± 6.8	22.2 ± 4.6	9.5 ± 2.3
Sandy/silt	49.2 ± 13.4	9.0 ± 6.9	14.4 ± 6.0	3.5 ± 3.0	15.1 ± 9.1	4.4 ± 1.4	15.2 ± 9.1	19.8 ± 11.7	15.2 ± 4.5	13.4 ± 4.1
Silty/clay (mud)	--	7.5 ± 7.5	--	1.1 ± 1.1	--	--	9.1 ± 9.1	--	2.4 ± 2.2	2.7 ± 2.7
Soil/loam (within floodplain)	34.5 ± 13.3	43.2 ± 10.0	17.7 ± 5.5	18.0 ± 9.1	66.3 ± 19.9	63.5 ± 4.2	64.6 ± 14.6	48.0 ± 17.5	27.5 ± 4.8	61.4 ± 5.8

-- = values < 1.0

Table 8. Comparison of surficial sediment composition between unregulated and regulated streamflow reaches within the Sycamore Alluvial Woodland sites. Percent values are mean ± standard error.

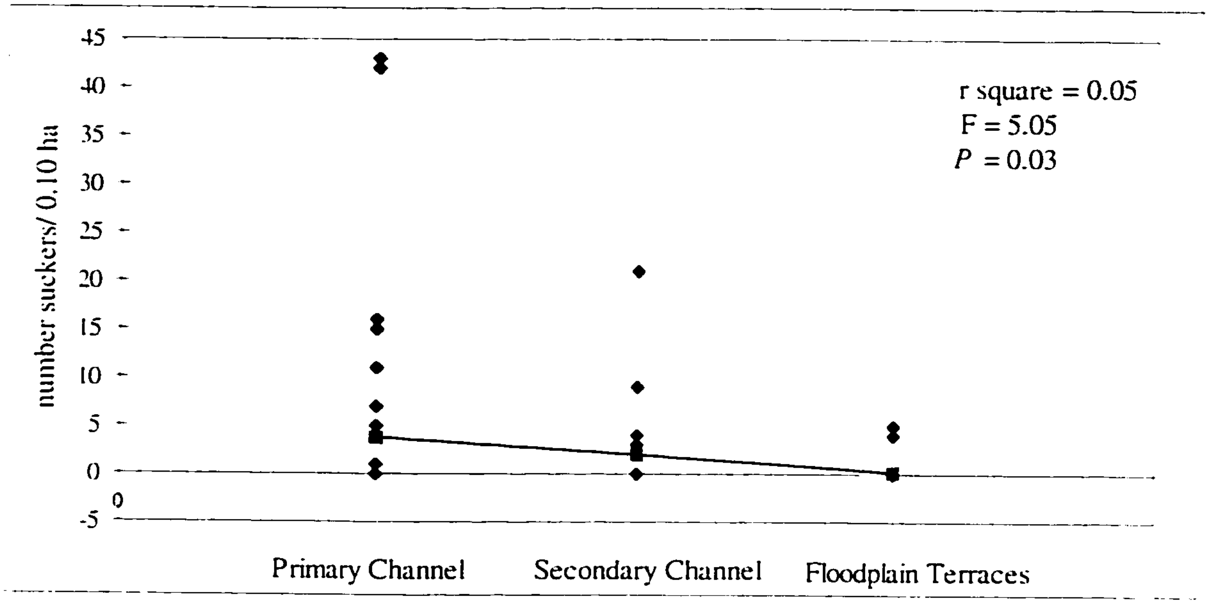
	Free Flowing Reaches (n=21)	Regulated Streamflow Reaches (n=20)	ANOVA *P*-value	$P < 0.05$
Sediment Size Class				
Cobble/medium gravel	32.7 ± 5.8	12.9 ± 2.8	0.004	*
Fine gravel/coarse sand	22.2 ± 4.6	9.5 ± 2.3	0.02	*
Sandy/silt	15.2 ± 4.5	13.4 ± 4.1	0.76	
Silty/clay (mud)	2.4 ± 2.2	2.7 ± 2.7	0.93	
Soil/loam (within floodplain)	27.5 ± 4.8	61.4 ± 5.8	0.00006	*

* indicate significant result

Geomorphic Relationship with Sycamore Regeneration

All regeneration of *P. racemosa* observed within the study sites was vegetative (asexual) or clonal growth (e.g., sucker shoots), with none of the study sites, free flowing or regulated, showing any evidence of sexual reproductive regeneration (seedlings). The combined quadrat data (n=97) from all sites showed that the relationship (ANOVA P = 0.03) of *P. racemosa* vegetative regeneration is greatest in and adjacent to primary channels and lowest on the terraces. Figure 11 shows the linear relationship of *P. racemosa* vegetative regeneration with geomorphic features within the study sites where the abundance of *P. racemosa* sapling/sucker growth is greater for areas nearest to primary and secondary stream channels and least for floodplain terraces.

Figure 11. Simple linear regression analysis of *P. racemosa* sapling/sucker growth in relation to geomorphic features of the Sycamore Alluvial Woodland (n = 97).



<u>Grazed vs. Ungrazed</u>

Non-native, understory cover and sapling/sucker densities of woody species were compared at the grazed and ungrazed/limited grazing sites. The non-native cover values at the grazed ($\overline{x}$ = 70.0%) and ungrazed ($\overline{x}$ = 73.2%) were very similar between the sites (Table 9). The mean *P. racemosa* sapling/sucker densities at the grazed sites ($\overline{x}$ = 39.5/0.10 ha) more than doubled those at the ungrazed sites ($\overline{x}$ = 15.9/0.10 ha), however, this difference was not significant (ANOVA $P = 0.24$). The *P. racemosa* sapling/suckers sampled in the grazed plots showed little to no physical evidence of direct browsing by cattle.

Table 9. Absolute density of young trees and cover by non-native species at grazed and ungrazed Sycamore Alluvial Woodland sites, Alameda and Santa Clara counties, California. Species, density, and cover values identified for ungrazed sites include Arroyo Del Valle and Coyote Creek and grazed sites include lower San Antonio Creek and North Fork Pacheco Creek each located within regulated streamflow reaches. Riparian species included *Platanus racemosa*, *Populus balsamifera* ssp. *trichocarpa*, and *S. lasiolepis*. Upland species included *Aesculus californica*, *Quercus agrifolia*, *Q. douglasii*, *Q. lobata*, and *Umbellularia californica*. Density values are mean/0.10 ha ± standard error. Cover values are mean ± standard error.

Scientific Name	Ungrazed Sites (n=34)	Grazed Sites (n=20)	ANOVA *P*-value
Overstory Density			
Platanus racemosa	15.9 ± 8.0	39.5 ± 22.0	0.24
Riparian Species	15.9 ± 8.0	44.0 ± 21.9	0.16
Upland Species	13.5 ± 8.8	4.0 ± 2.5	0.42
Understory Cover	(n=11)	(n=9)	
Non-native Grassland	62.4 ± 8.4	59.2 ± 5.4	0.77
Total Non-native Species	73.2 ± 5.7	67.8 ± 5.9	0.52

-- = values < 1.0

DISCUSSION

The vegetation and physical structure of stream reaches below Del Valle Reservoir, San Antonio Reservoir, Anderson Reservoir, and Pacheco Reservoir in the Mount Hamilton Range have been altered from natural conditions. These reaches differed significantly in vegetation composition and surficial sediment composition from the control reaches, which were stretches either upstream from the reservoirs or were free flowing streams.

Two of the greatest changes to the Sycamore Alluvial Woodland in reservoir reaches were the presence of non-native species and reduction of open ground areas within the understory. Analysis of the understory structure showed that annual grassland and other non-native species have significantly increased below reservoirs. Bare ground was also significantly reduced. In undammed conditions, as shown by the control reaches, streams receive high flows that would typically remove vegetation within the floodplain. The control sites typically had more open ground with low vegetative cover and lower cover by annual grassland. The installation of these reservoirs has limited the natural high peak flow regimes within their floodplain, reducing the removal rate of non-native, understory vegetation that has encroached into the floodplain.

The reduction of streamflow and lessening of floodplain inundation below reservoirs was also expected to provide a medium for the establishment of adjacent upland community species (i.e., oak woodland species components) encroaching within the Sycamore Alluvial Woodland. Other studies where flows have been altered demonstrated an increase in upland species abundance (Stromberg and Patten 1989). The data presented, however, do not suggest that this is occurring in the study area. Because this community is typically intermittent (Holland 1986, Sawyer and Keeler-Wolf 1995), some upland species may naturally occur within this community type. Both control and regulated flow sites had similar cover of upland, overstory species including *Aesculus californica*, *Quercus agrifolia*, *Q. lobata*, and *Umbellularia californica*. Although the differences were not significant, there was evidence that the density of these upland species may be increasing by becoming more established as peak streamflows and floodplain inundation remain limited by the reservoirs (Table 5).

Another factor that has influenced changes in the Sycamore Alluvial Woodland riparian type below reservoirs is the unnatural availability of water from reservoirs. Historically, most of these streams were intermittent under conditions with large pulses of flow during the winter and dry periods during the summer (Sharsmith 1945). However, the reservoirs create a perennial source of water directly below and downstream of the reservoirs by stream flow discharges during the summer. My analysis of the overstory composition showed that the continuous availability of water has allowed the establishment of phreatophytic species other than *P. racemosa*, including *Populus balsamifera* ssp. *trichocarpa*, *P. fremontii* ssp. *fremontii*, *Salix exigua*, *S. laevigata*, and *S. lasiolepis*. This change from the natural water regime is expected to contribute to a community type conversion from a Sycamore Alluvial Woodland to a more mixed riparian woodland as has had been suggested by Keeler-Wolf et al. (1994). Barnes (1997) also found changes in species diversity and shifts in the overstory composition following dam installation on the Chippewa River in Wisconsin. The data provided in Table 5, depicting a significant increase in riparian species, support this trend of community change in overstory species composition. This community type conversion from a relatively low species rich community dominated by *P. racemosa* to more of a mixed riparian woodland type is a subtle, indirect result of upstream reservoirs. This type of community conversion becomes detrimental to the natural integrity of the Sycamore

Alluvial Woodland community type where altered streamflows will continue to affect species composition, diversity, and community dynamics.

The reduction of natural streamflow below these reservoirs has also reduced transport of cobble and gravel sized sediments, one of the greatest impacts to stream channels and riparian areas downstream from large dams (Debano and Heede 1987). A common geomorphic channel pattern in the Sycamore Alluvial Woodland community is a braided stream channel morphology (Holland 1986) and this is typically associated with areas of high discharge and greater amounts of coarser material (Leopold and Wolman 1957, Allen 1965, Osterkamp 1978). As expected, the surficial sediment composition at the sites below reservoirs showed a significant decrease in larger sediment sizes from coarse sand to cobble and a significant increase of soil/loam compared to the control sites. This change can be detrimental to the Sycamore Alluvial Woodland riparian type because of *P. racemosa* dependence on the transport of coarser sediment material for regeneration.

The linear regression presented in this study (Figure 11) showed a relationship that abundant regeneration via sucker growth occurs within the active stream channel. This is consistent with findings from Finn (1991) and Bock and Bock (1985) who studied two western North American sycamores (*Platanus racemosa* and *P. wrightii*). These researchers found that sycamore regeneration occurs nearest the stream channel, an area that is typically influenced by coarser alluvial sediments and scouring. Similarly, studies on the eastern North American sycamore (*P. occidentalis*) indicate that regeneration was optimized in areas of coarser sized sediment substrates (Sigafoos 1976, Hupp and Osterkamp 1985, Boerner and Cho 1987, Sampson 1930, and Gordon 1969).

Several researchers have found negative effects of grazing on riparian systems including lower to no regeneration, bank erosion, and changes in vegetation composition

(Szaro 1989). It has been suggested by Keeler-Wolf et al. (1994) that grazing has a detrimental effect on the Sycamore Alluvial Woodland by lowering regeneration rates of *P. racemosa* and increasing non-native species within the community. However, this study found no significant differences in *P. racemosa* regeneration and non-native cover between grazed and ungrazed sites. This finding is consistent with Smith (1989) and Finn (1991) who found few direct effects of cattle grazing on sycamores. Glinsky (1977) and Martin (1979) also found that this species was typically unpalatable to cattle. The main contributing factor of consistently high cover of non-native species in the grazed and ungrazed sites is their location downstream of reservoirs. The reduction of high flood flows by the reservoirs in these downstream reaches may not create the natural disturbances necessary to remove non-native species within the floodplain.

MANAGEMENT IMPLICATIONS

Studies that have examined the effects of regulated streamflow on riparian communities found negative impacts, including riparian forest decline, vegetation type conversion, lower regeneration rates, and slower growth rates (Barnes 1997, Reily and Johnson 1982, Howe and Knopf 1991, Stromberg and Patten 1989, 1992a, 1992b, Fenner et al. 1985, Bradley and Smith 1986, Rood and Heinze-Milne 1988, Bravard et al. 1986, Szaro and DeBano 1985, Johnson et al. 1976, Smith et al. 1989). In many of these studies, researchers suggested returning streamflows to their natural flow pattern to lessen negative impacts to these riparian systems. Attempts to understand sensitive or rare environments that depend on certain physical and biological parameters are necessary to determine how to manage and protect these sensitive habitats. Providing information on a specific natural community or species can contribute to delimiting management concerns and protecting the integrity of natural ecosystems and their associated species.

The Sycamore Alluvial Woodland is a rare plant community in California threatened further by reservoir projects. Reservoirs are highly detrimental to riparian systems by completely inundating stands and destroying them directly. This study found that reservoirs also have long-term indirect impacts on downstream communities including coarse sediment load deficiencies and vegetative changes. Downstream sites differed significantly in surficial sediment composition, overstory species composition, open ground, and non-native cover. Only approximately 800 hectares (2,000 acres) of Sycamore Alluvial Woodland are left in California and many of these sites suffer from the indirect effects of reservoirs. The Department of Water Resources is planning to directly inundate one of California's largest Sycamore Alluvial Woodland stands with the proposed installation of Los Banos Grandes Reservoir. The size of this stand makes up approximately 20 percent of the total remaining acreage of this riparian community throughout California and is considered the highest quality Sycamore Alluvial Woodland stand left in California (Keeler-Wolf et al. 1994). Given the rarity of this resource, existing Sycamore Alluvial Woodland should be protected from such direct losses.

Data provided from this study and other studies indicate that reservoirs also indirectly affect this community downstream as the result of altered streamflow regimes. The primary result of this impact is a conversion from a community type dominated by *P. racemosa* to a mixed riparian type where *P. racemosa* is a codominant species with other riparian macrophytes, including *Salix* spp. and *Populus* spp. Other riparian species may increase as a result of the persistent availability of water being released from the reservoir. Increased cover by non-native species is another negative effect of water impoundment. The composition of surficial sediment changed as the result of upstream reservoirs within this community (i.e., decreased discharges of larger sediment sizes) may also be detrimental to those species dependent on specific sediment sizes, including *P. racemosa*.

In Sycamore Alluvial Woodland areas that are affected by altered streamflow patterns, the best management recommendation is the possible implementation of releasing high flood flows during appropriate times that may imitate natural flood flow regimes. This strategy has also been suggested by Bradley and Smith (1986) and examined by Kondolf et al. (1987). The optimal time of such reservoir releases would be in late winter to spring to benefit *P. racemosa* potential seedling recruitment and sucker establishment. Implementation of high stream flow releases would require monitoring or follow-up assessments on how this type of management practice affected the community. Specific parameters to monitor include channel morphology, evidence of recruitment, erosion, sediment distribution, and community composition. Other Sycamore Alluvial Woodland topics that require further research include fluvial processes, groundwater, climate, and how these physical conditions interact with this specific community type and distribution.

Recreation development within the Sycamore Alluvial Woodland community type may also be detrimental depending on the type of development. A recreation and wildlife project had been proposed for the free flowing Sycamore Alluvial Woodland site occurring on the Orestimba Creek in the southeastern part of the Mt. Hamilton Range in western Stanislaus County (Morris 1981). The proposal included converting a portion of the naturally intermittent stream to a perennial stream by augmenting flows from the California Aqueduct and introducing new plant species to the community. This type of development is strongly discouraged because of the direct impact on the community structure by introducing different species to the natural community and the indirect impact by altering the natural streamflow regime.

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Appendix A

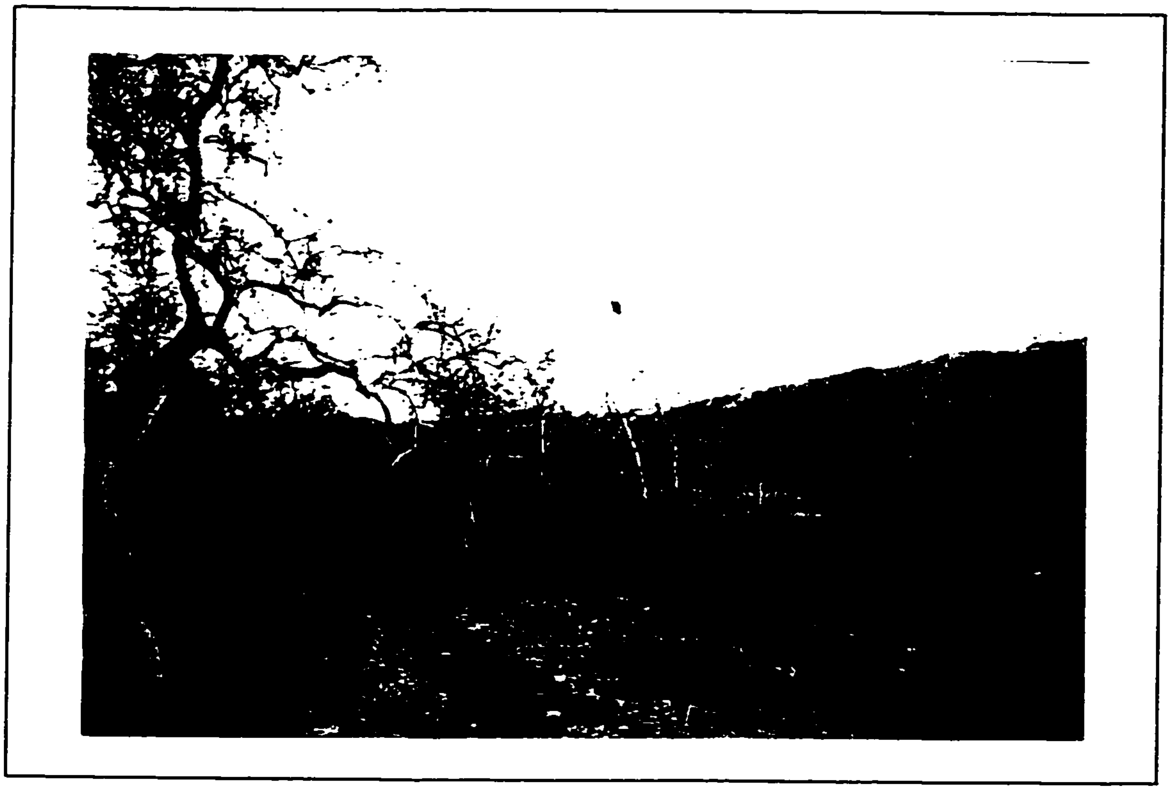


Plate 1. Upstream Arroyo Mocho Control Stream Reach: Primary and Secondary Channel, Grazed Site (April 4, 1998)

Plate 2. Upstream Arroyo Mocho Control Stream Reach: Primary Channel, Grazed Site (April 4, 1998)

Plate 3. Downstream Lower San Antonio Creek Regulated Stream Reach: Primary Channel, Grazed Site (August 14, 1995)

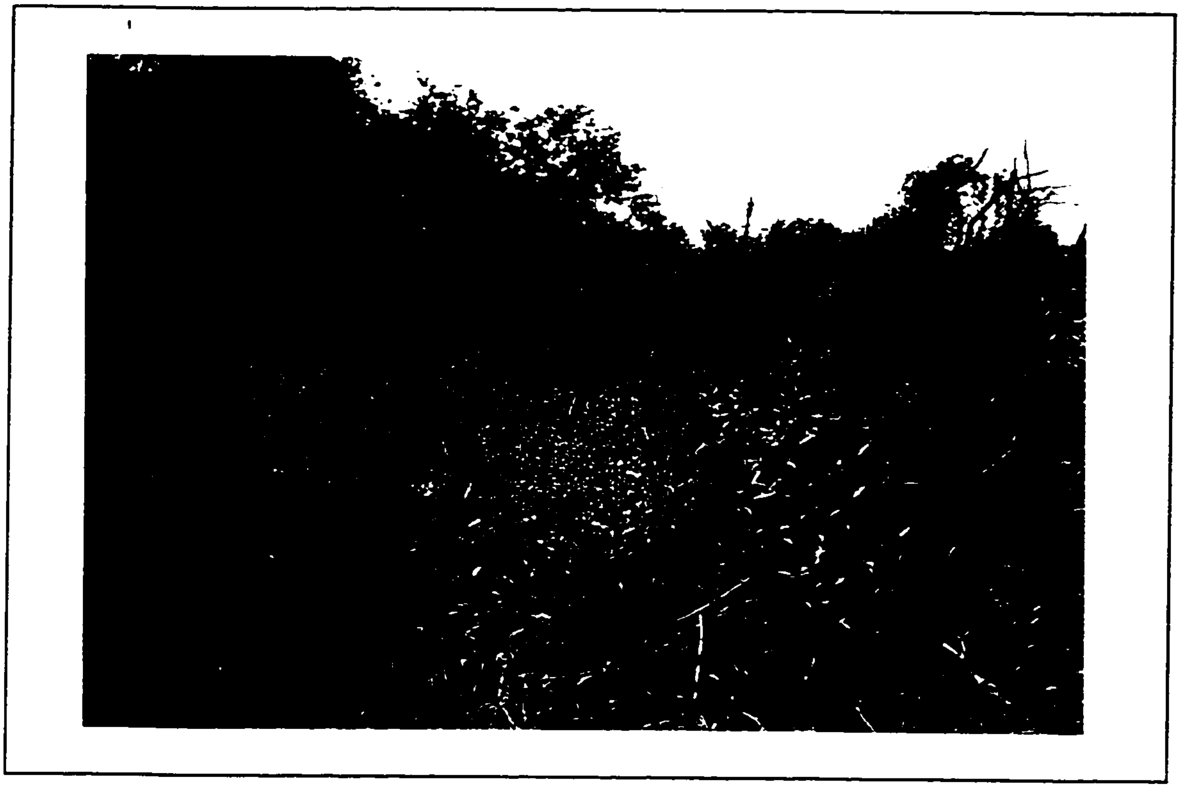


Plate 4. Downstream Lower San Antonio Creek Regulated Stream Reach: Primary Channel, Grazed Site (August 14, 1995)

Plate 5. Downstream Upper San Antonio Creek Control Stream Reach: Primary Channel, Grazed Site (August 14, 1995)

Plate 6. Upstream Upper San Antonio Creek Control Stream Reach: Primary Channel, Grazed Site (August 14, 1995)

Plate 7. Upstream Lower Coyote Creek Regulated Stream Reach: Primary Channel, Ungrazed Site (April 8, 1998)

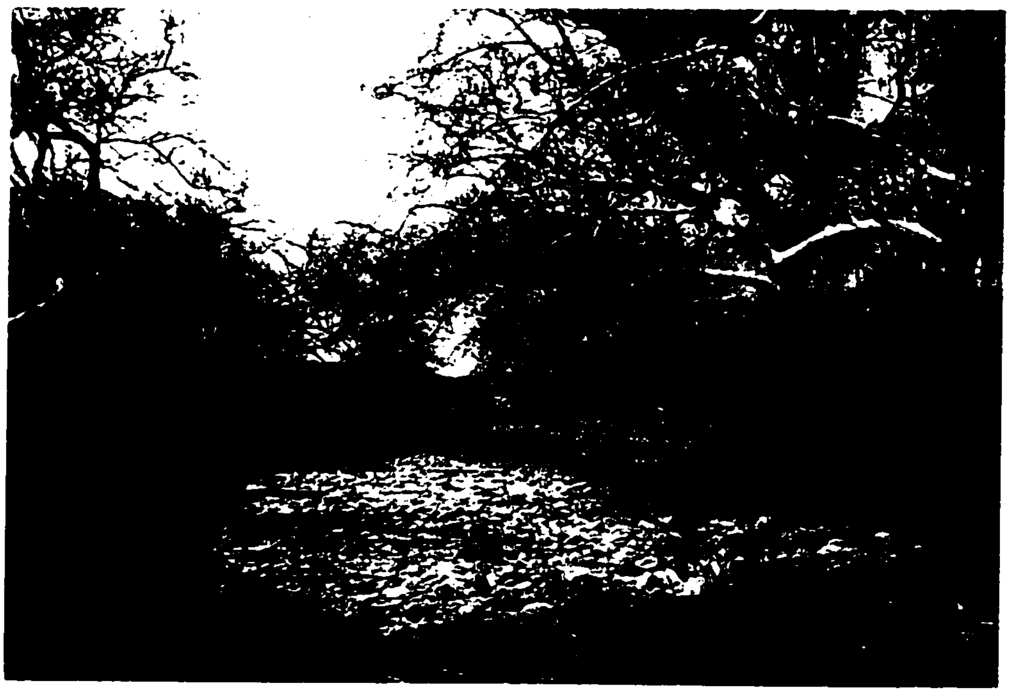


Plate 8. Upstream Lower Coyote Creek Regulated Stream Reach: Secondary Channel, Ungrazed Site (April 8, 1998)

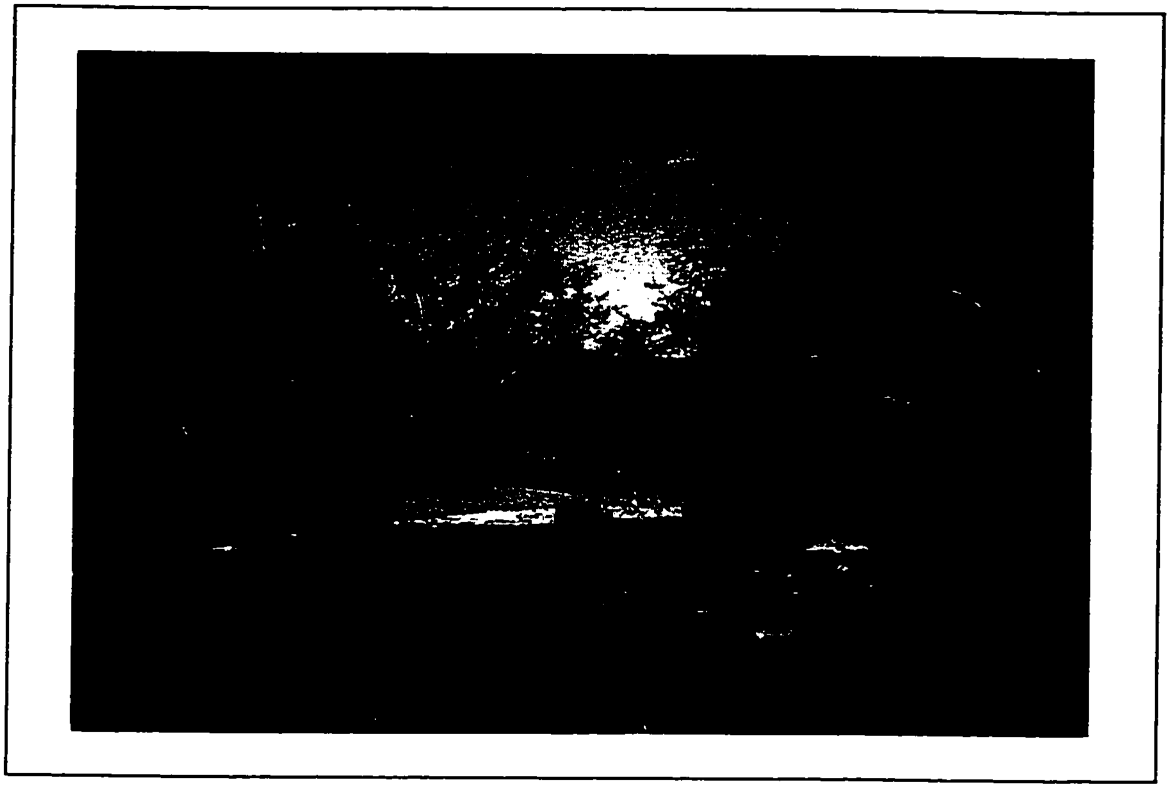


Plate 9. Downstream Arroyo Mocho Control Stream Reach: Primary Channel, Grazed Site (April 8, 1998)

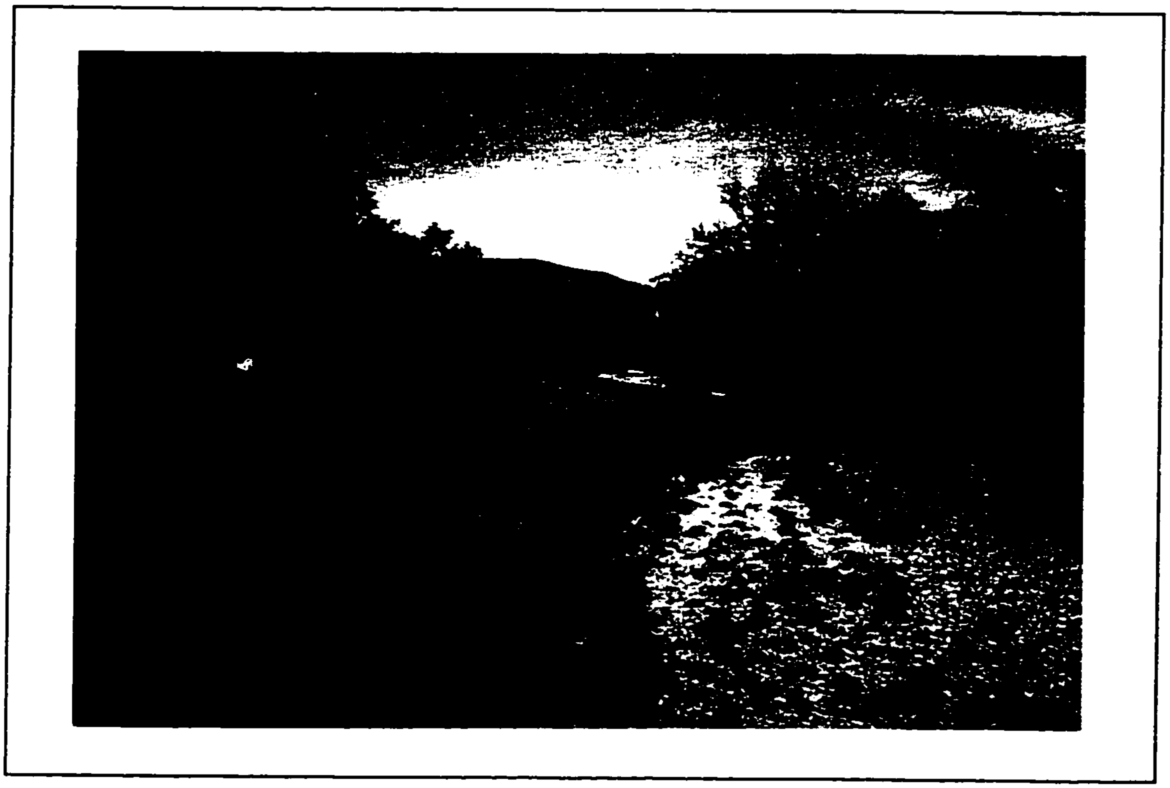
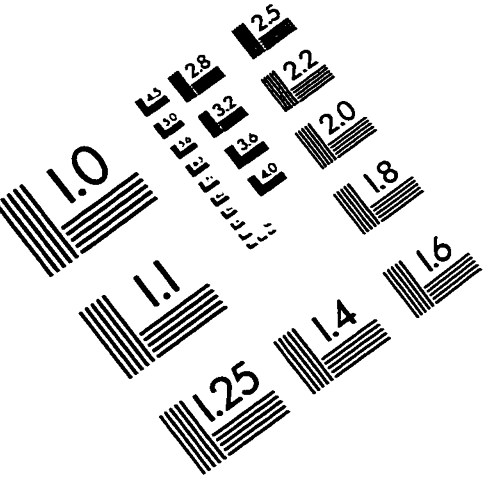


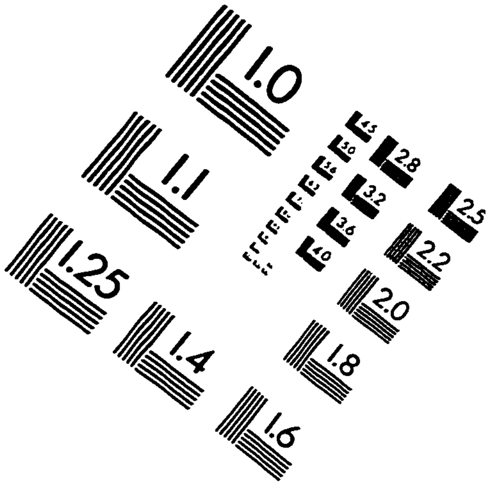
Plate 10. Upstream Lower San Antonio Creek Regulated Stream Reach: Primary Channel, Grazed Site (April 8, 1998)

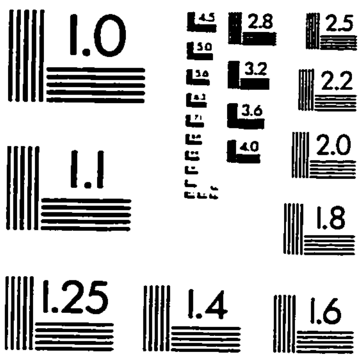
Plate 11. Downstream Arroyo Del Valle Regulated Stream Reach: Primary Channel, Ungrazed Site (July 1, 1995)

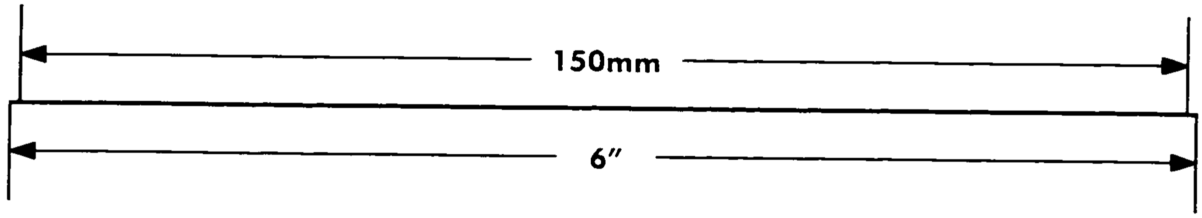
Plate 12. Upstream Arroyo Del Valle Regulated Stream Reach: Secondary Channel, Ungrazed Site (July 1, 1995)

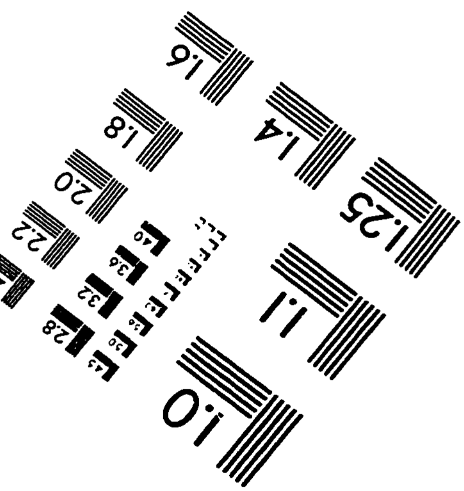
IMAGE EVALUATION TEST TARGET (QA-3)

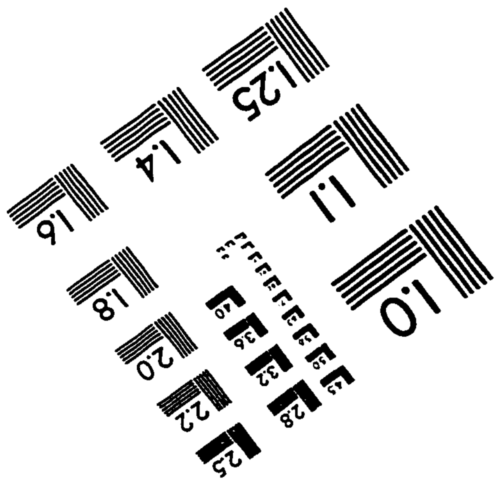












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